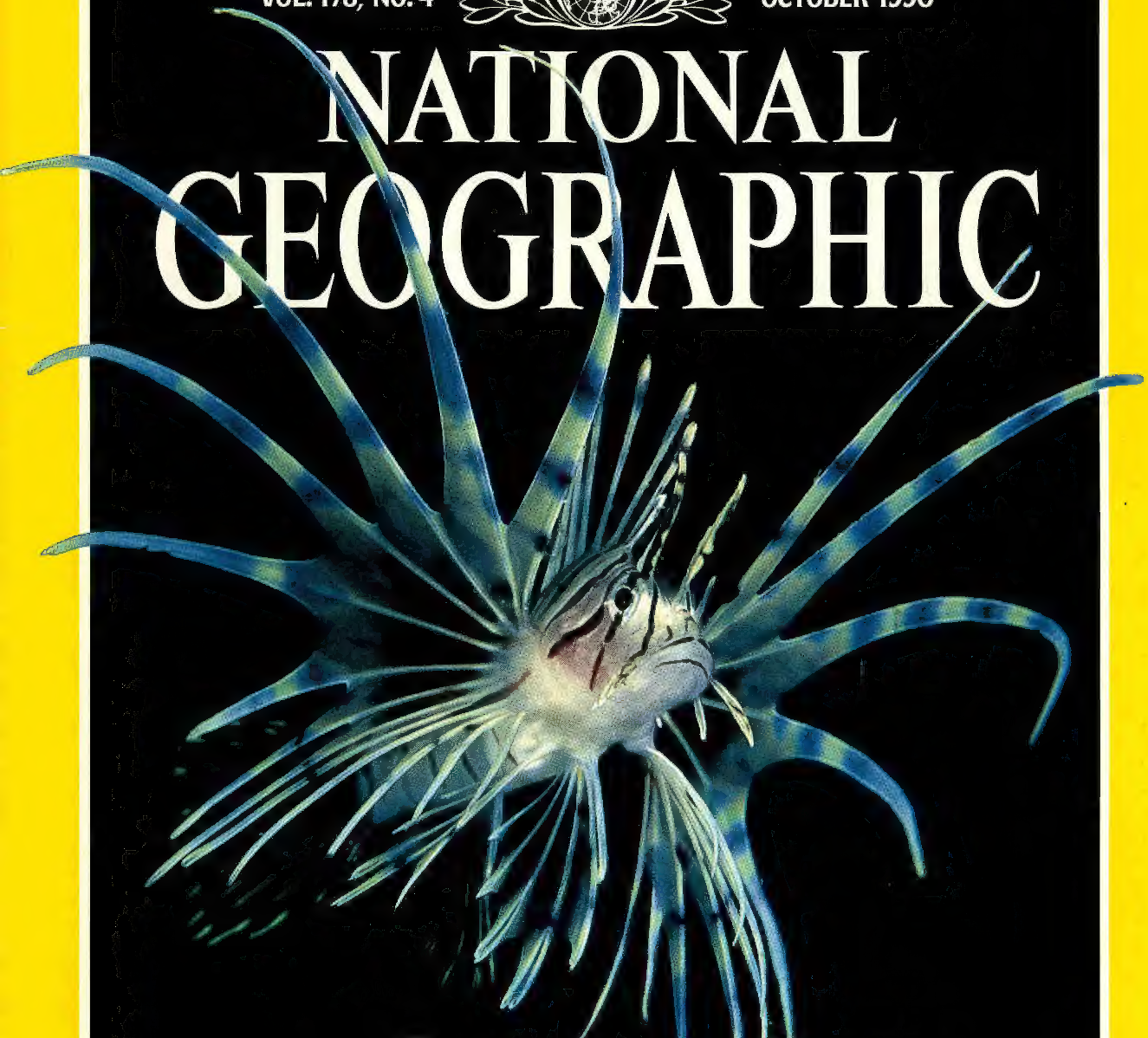
VOL. 178, NO. 4 OCTOBER 1990

NATIONAL GEOGRAPHIC



SURUGA BAY
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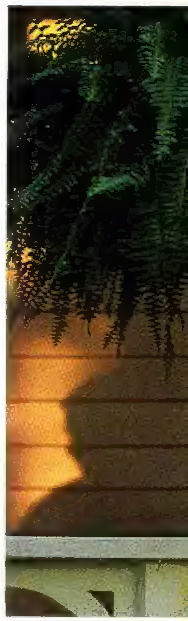
OFFICIAL JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY WASHINGTON, D.C.

RON LORY *is an autoworker, a father of three and a lifelong St. Louis baseball fan. He and his family have strong ties to the Midwest. Here, he tells why, despite the risks, he uprooted his family and left a secure job to come help build the brand new Saturn cars in Spring Hill, Tennessee.*

"...I'm a St. Louis boy, and my wife is a St. Louis girl. I raised my family there and worked at a car plant thirty miles out.



I enjoyed what I was doing, but you reach a point in your life when you look at the future and decide to do something for no other reason than just believing it's right.

For me, Saturn was the chance to make a difference. To prove I have a mind, that I'm more than just a pair of hands.

I wouldn't have moved my family four hundred miles just to fail. Then have to pack them up and move again.

My wife had to leave a house she loved. A nice three-bedroom with a full basement and a patio in the back.

My 16-year-old was convinced we were

© 1990 Saturn Corporation

ruining her life. Her first serious romance, and all. I wouldn't have made the move unless the whole family said 'Let's go for it,' and my daughter knew it. So she decided to try. You know, I'm really proud of her for that.

Funny story. When I first heard about

Saturn, I came home and we started hauling out the maps, looking for Spring Hill. 'Where's Spring Hill?' Sure enough, it's right in the middle of the fold and we couldn't find it.

SATURN

Now, can you imagine trying to talk a couple of teenagers into moving to a town that's smaller than their high school?..."

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FROM THE PRESIDENT

Yosemite: 100 Years Later

THE NATIONAL GEOGRAPHIC SOCIETY

AS WE CELEBRATE THE CENTENNIAL of Yosemite National Park this month—recalling our favorite memories of breathtaking cascades, granite domes, alpine meadows—we should keep in mind that our expectations for this remarkable place have always bordered on the unattainable.

From the very beginning, every visitor has wanted to feel the rare beauty of Yosemite for himself, to share the rapture felt by the great naturalist John Muir as he admired the heroic cliffs and the way "the winds and avalanches and clouds shine and sing and wreathe about them as the years go by."

COURTESY HAGGIN MUSEUM, STOCKTON, CALIFORNIA

"Every rock in its walls seems to glow with life. . . . bathed in floods of water, floods of light," wrote John Muir in 1912. Albert Bierstadt's 1868 oil painting "Sunset in the Yosemite Valley" captures the same sense of power and glory experienced by millions of visitors to the national park during its first century.

At the same time, we have democratically insisted that everyone who wants to should have the right to enjoy such pleasures and that it is the duty of government, in the words of Frederick Law Olmsted, "to give every advantage practicable to the mass of people" to visit the park.

These apparently contradictory goals—in which we seek to minimize human intrusions upon the natural setting while attempting to maximize the number of individuals who experience it—have led our nation to designate 94 percent of Yosemite National Park as permanent wilderness while permitting 3.5 million people a year to drop by. We've reintroduced native bighorn sheep to remote areas of the park, but we weren't able to prevent the 578 automobile accidents that took place last year in Yosemite Valley.

"Yosemite evokes passionate arguments because it calls up powerful contradictions," states Randolph T. Hester, Jr., of the University of California at Berkeley: "urbanized wilderness, abused jewel, paradise commercialized, unnatural nature." No wonder those who love Yosemite tend to argue a lot. We've never managed to agree as a nation exactly what we want this park—or any national park, for that matter—to be. We want it to be many things for many people: backpackers, rock-climbers, bird-watchers, campers, kids from the inner city, senior citizens. And yet we want the place to look exactly the way it was more than a century ago when the Miwok Indians called it home.

That's a tall order for the National Park Service, which has struggled along in recent years with exceedingly slim budgets, and for friends of the park such as the Yosemite Association, the Yosemite Institute, and the Yosemite Fund, which channel private funds and enthusiasm into park projects. Considering the many demands we put on the park—and our unreasonable expectations—the most surprising message of Yosemite after a hundred years, as Kenneth Brower writes in the 1990 Society publication *Yosemite: An American Treasure,* "is not how badly the park is run but how well."

Gilbert M. Grosvenor

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FORUM

Greenways

Your excellent article "Greenways: Paths to the Future" (June) is a powerful help and inspiration for all Canadians who advocate the rails-to-trails conversion. It comes at the right time. Here in Prince Edward Island, Canada's smallest province, all train service has been discontinued during the past few months. We have nearly 300 miles of unused railways that could advantageously be turned into greenways.

ROGER TREMBLAY
Charlottetown,
Prince Edward Island

The statement that "some 3,000 miles of railroad tracks go out of service every year . . . their transportation replaced by trucking" is true for only a fraction of the abandonments. Some have come about after competing railroads merged into larger corporate systems—like Burlington Northern and Conrail, which then trimmed away duplicate routes. Many branch lines are being abandoned because railroads are devoting more attention to "land bridge" handling of transoceanic cargo containers from both coasts, a business in which railroads are clearly ousting trucks.

BRUCE KELLY
Railfan & Railroad *Magazine*
Newton, New Jersey

You gave too short shrift to Sacramento's magnificent 23-mile-long American River Parkway by showing only a picture of a homeless man. Most vagrants are confined to the lower two miles. The rest of the bikeway is a delightful eight-foot-wide paved strip along the river, where we see deer, rabbits, coyotes, and a host of birds.

ROBERT H. PASCHALL
Sacramento, California

Rural people have seen their world destroyed by the Pony Express, telegraph lines, railroads, highways, airports, and low crop prices. The final blow to rural America is the national greenway network.

JAMES CHOJNACKI
West Hamlin, West Virginia

In the heart of Anchorage we have almost 50 miles of paved trails for bicycling and skiing, surrounded by a broad greenbelt that stretches 12 miles along the coast and reaches almost 10 miles through town to the Chugach Mountains. These trails connect to a network of a hundred miles of unpaved homesteading roads and trails that are now closed to motorized traffic within municipal boundaries. On the city trails year-round you can meet moose, brown bears, bald eagles, skiers, and runners. The only problem is the delays caused by moose that occupy the trails and refuse to move after they've found a birch tree to munch.

ERIC LARSON
Anchorage, Alaska

I suggest a further refinement to the expansion of greenways: the Trans-America Trail. It seems surprising that in a country with a history of east-west exploration and settlement (and much of that on foot), we don't have even one transcontinental hiking trail. It could have an eastern terminal at the Statue of Liberty or Washington, D. C., or Jamestown and a western terminal at the Golden Gate Bridge. By following and crossing existing public lands wherever possible, much of the trail's route is already in place.

PAT HASTINGS III
Arlington, Texas

Austin

I'm sure that Elizabeth Moize's article "Deep in the Heart of Texans" (June) was as therapeutic for other ex-Austinites as it was for me. It brought back fond memories of growing up there in the 1970s. Shoot, we were digging up shark teeth in Shoal Creek before anybody else ever thought about excavating there. You can take Bubba out of Austin, but you can never take Austin out of Bubba. Hook 'em horns!

LEE FREDERICK
New Orleans, Louisiana

For the most part a "Bubba" is intolerant, racist, sexist, and ignorant. Attempts to celebrate the exclusionist good ol' boy values of redneck culture are distasteful and misleading.

JOE GIBSON
Red Deer, Alberta

The article was appallingly biased. Many former residents refer to Austin as Tacky Town, Austintatious, Home for the Unpleasant, Refuge for the Ill-mannered, and even less complimentary epithets. Not all those familiar with the Athens of Texas are as stuck on Austin as a segment of Austin is stuck on itself.

GUIDO RILEY
Albuquerque, New Mexico

I'm a temporarily transplanted Austinite, serving as a Peace Corps volunteer on St. Kitts. Your vivid pictures and words portrayed the honor, pride, and depth of affection we Austinites feel. Now my fellow volunteers and West Indians can see why I'm so Austin-proud.

LYNN COCKERILL
Basseterre, St. Kitts

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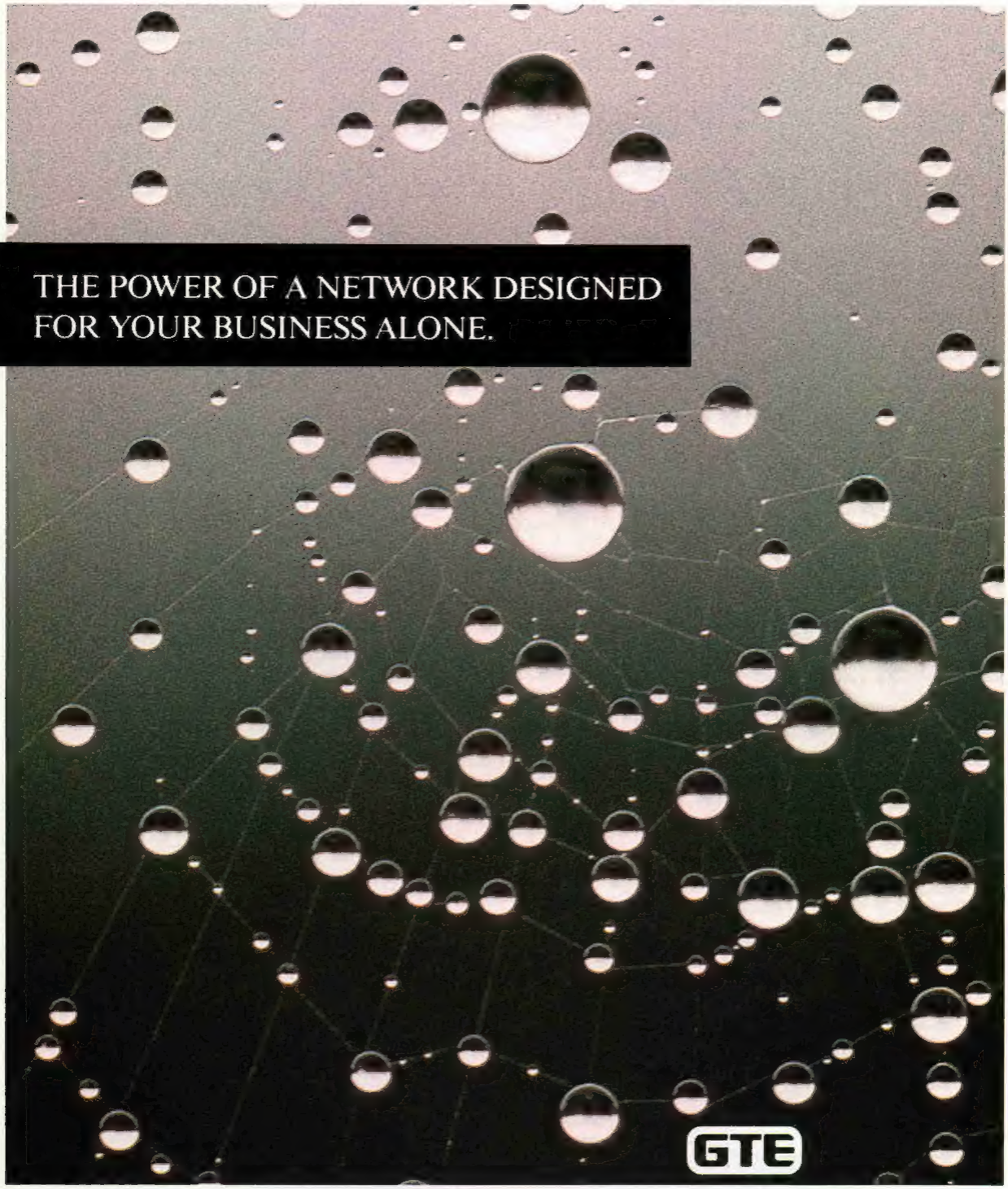


THE POWER IS ON

As a graduate student at the University of Texas, I spent two happy and memorable years in Austin. I cannot imagine this damn Yankee being treated better or more warmly anywhere else in the South. Of course that assumes that Texas is in the South. I think it is a region all to itself, with Austin its shining "lone star."

REED LIMING
Fort Myers, Florida

I can't believe that you did not include a picture of the Treaty Oak.

UGO LOUIS DEFEO
Staten Island, New York

The latest word from the city forester is that the Treaty Oak has lost two major limbs as a result of malicious poisoning, but one huge limb survives and the tree will live.

Dominica

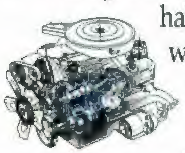
Robert Booth and photographer Bruce Dale were remarkably successful in capturing the essence of this powerfully beautiful and surprisingly complex island nation (June). However, there is no archaeological or linguistic support for claims of cannibalism by Carib Indians. Caribs may have used the issue centuries ago to help keep Europeans at a distance. Ethnographer Douglas Taylor, who knew them and the earliest French missionary accounts

More mus

The new mid-size Dodge

More payload than standard Ford and Chevy half-tons.

Its agility approaches compacts. Its payload capacity holds its own against that of meatier half-tons. And with available V-8 power, it's the best all-around pickup on the road. It's the new mid-size Dodge Dakota.*



We revved up our Dakota with a 170 hp V-8.

Flexes new V-8 muscle.

To any skeptic who thinks

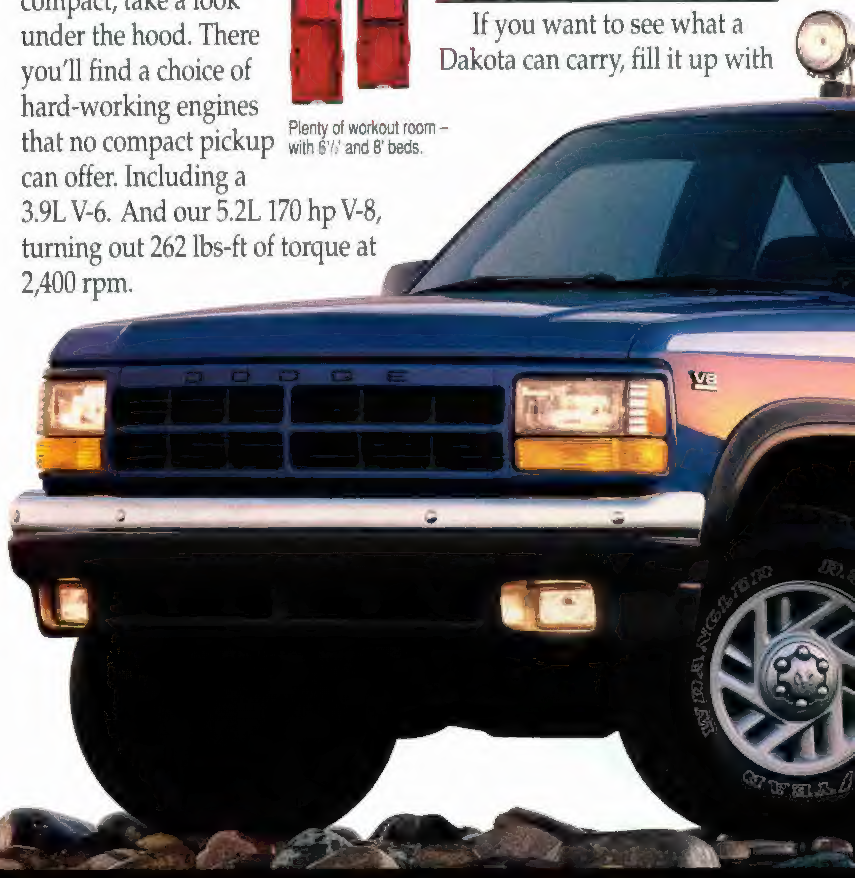
Dodge Dakota 4x4 Sport

Dakota's a dressed-up compact, take a look under the hood. There you'll find a choice of hard-working engines that no compact pickup can offer. Including a 3.9L V-6. And our 5.2L 170 hp V-8, turning out 262 lbs-ft of torque at 2,400 rpm.

Plenty of workout room – with 6'½' and 8' beds.

Equipped for heavy loads.

If you want to see what a Dakota can carry, fill it up with



better than anyone else, denied they were cannibals. But the myth is always repeated.

ROBERT A. MYERS
Assoc. Professor of Anthropology
Alfred University, New York

The article was accurate and insightful with one exception. There are more than half a dozen Americans on Dominica. From 80 to 120 at any given time are studying at our campus south of Portsmouth, and our medical faculty includes 11 U. S. citizens.

JAMES E. CASSIDY
President, Ross University
New York, New York

The statement referred to permanent residents.

Your article neglected to mention that Jean Rhys, celebrated author of *Wide Sargasso Sea,* was born in Roseau in 1890. Her father was a doctor, a recent arrival from Wales, and her mother's family had been there for generations. Rhys lived on Dominica until age 16, when she went to school in England. She returned only once, in 1936.

ANN SPARK
New York, New York

About 20 years ago I had the pleasure of touring Dominica. What stood out, besides the pristine beauty of the rain forest, were delightful meals of "mountain chicken," as Dominicans call the large,

cle, less fat.

Dakota. Now with V-8 power.

a load of topsoil. We've got up to 2,550 pounds of available payload, depending on engine and model. Standard Chevy and Ford half-tons can't haul as much. And though it's lighter than Chevy C1500, Dakota can carry 300 pounds *more.*** Not bad for a truck that's a lot leaner than its full-size competition.

Bodies of all sizes and shapes: 4x4, 4x2 and Club Cab.

The body you always wanted.

Take your pick of Dakotas. From 4x2, 4x4, longbed, shortbed, Club Cab and Sport models. Every one has been restyled for 1991.

Welcome home to Dodge.

America is coming home to Dodge. And with trucks like Dakota V-8 and our full-size Cummins Diesel, the only turbo diesel pickup you can buy, we think they're home to stay. Come see what we're made of.

*Competitive claims based on '90 data ('91 competitive data incomplete at time of printing.) **Available regular cab 4x2 payload comparisons.

Buckle up for safety.

Advantage: Dodge.

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Think Think
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Think Think
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Think Think
Think Thanks

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tender legs of frogs culled from mountain pools. Have they been eaten to extinction?

BASIL ZAROV
Toronto, Canada

They have not; the author laments that they were out of season during his visit.

Moche

Having studied pre-Columbian art at Tulane University, I enjoyed "Splendors of the Moche" (June). But doesn't the headdress on page 12 bear a stylized representation of a bat rather than an owl?

CRAIG JOHNSON
St. Paul, Minnesota

No. The beak and talons are the diagnostic features. Ears appear often in Moche art on such creatures as frogs, snakes, and owls.

As a former American Field Service student in Chimbote, Trujillo, and Lima, I found it refreshing to read the three non-drug/terrorist/inflation-related articles about Peru. Unfortunately many people are unaware of the fascinating cultural traditions and archaeological sites Peru has to offer.

NICOLETTE LASSITER
Oconomowoc, Wisconsin

On page 28 it is stated that "no one knows why the curer [shaman] holds a hand to her mouth." In the June 1990 issue of *Alaska* magazine Marilyn Savage writes about her grandmother, who describes primitive surgery among the early Athabascans. She describes a shaman using spit to place a patient into deep sleep.

IRENE SODOLAK BLAZEK
Sealy, Texas

Perhaps the action of the pottery curer can be explained by the photograph of the modern counterpart on pages 46-7. The curer on the pot may likewise be placing an herbal mixture in her mouth and preparing to eject the spray toward the head next to her patient.

MARK G. LUTENBACHER
Metairie, Louisiana

Smallest Hummingbird

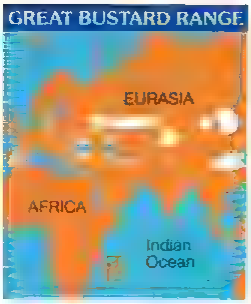
There is a mistake on page 73 of the June issue. Tyrrell did not obtain the "first photographic documentation" of the bee hummingbird. My 16-mm footage was earlier. Tyrrell's are certainly better quality than my movies.

JOHN W. MCNEELY
Sharon, Connecticut

Tyrrell's are the first published photographs of the bird.

Letters should be addressed to FORUM, National Geographic Magazine, Box 37448, Washington, D. C. 20013, and should include sender's address and telephone number. Not all letters can be used. Those that are will often be edited and excerpted.

WILDLIFE AS CANON SEES IT



Great Bustard
Genus: *Otis*
Species: *tarda*
Adult size:
Length, 75-105cm;
wingspan, 190-260cm
Adult weight: 8-16kg
Habitat: Lowlands, river valleys and open country in North Africa, Europe and Asia
Surviving number:
Estimated at 10,000
Photographed by
Konrad Wothe

A stately great bustard stands alert on its display grounds. Springtime brings a spectacular courtship ritual by the male bustard, when it struts, stamps, and unfolds its plumage into a billowing mass of white feathers. Already extinct in much of Europe, the great bustard is declining throughout its range as it steadily loses habitat to agricultural development. To save endangered species, it is essential to protect their habitats and understand the vital role of each species within the earth's ecosystems. Photography, both as a scientific research tool and as a means of communication, can help promote a greater awareness and understanding of the great bustard and our entire wildlife heritage.

EOS 1
The New Classic

Canon

We'd like to uncover a hidden natural resource.

Did you know that the empty plastic soft drink bottles you throw away every day can be transformed into carpet yarn or automotive parts or fiberfill for ski parkas?

That used glass bottles and aluminum cans can be transformed into new ones?

And that yesterday's newspaper can be transformed into tomorrow's?

It all happens because of recycling. The simple trash we throw away is a "natural resource" that, with recycling, can be used to produce a multitude of new products.

Unfortunately, America recycles only 10% of its garbage, incinerates 10% and deposits a whopping 80% in landfills. As a result, we are having to cope with a monumental solid waste problem.

Our landfills are going–going–gone.

Americans throw away about 160 million tons of garbage a year. According to a recent study, plastics make up about 18% of the volume of our solid waste; paper and paperboard account for about 38%; metals, 14%; glass, 2%; and other wastes, 28%.

As a result, in the past 10 years our country's landfills have decreased from about 18,500 to 6,000. In five years, 2,000 more will close.

In their haste to find solutions, some local legislatures have proposed to ban plastics.

Unfortunately, a ban on plastics would do much harm and no good. We would lose all of the safety, health and convenience features of plastics, such as tamper-resistant closures and shatter-proof bottles.

Moreover, packaging would still be needed. A 1987 study showed what would happen if plastics were banned—the energy needed to produce the alternative packaging, its weight, its cost, and the volume of waste collected would all rise dramatically.

What to do?

At Amoco Chemical, we believe part of the answer to America's waste problem lies in recycling everything from glass to metals to paper to plastic.

Today, recycling is on the rise. There are now more than 1,000 curbside separation recycling programs across the country. Many are beginning to incorporate plastics.

Right now, almost 200 companies are recycling millions of used plastic containers into paint brush bristles, traffic signs, toys, floor tiles, waste-baskets and "plastic lumber" for decks and park benches.

Plastics are among the easiest materials to recycle. More than 150 million pounds, or 20% of all plastic soft drink bottles, were recycled in 1987.

How Amoco Chemical is helping.

Amoco Chemical is sponsoring a recycling program in New York demonstrating that used, polystyrene foam food service containers from schools and restaurants can be recycled into insulation board for commercial construction, cafeteria trays and home and office products.

We're participating in a consortium with other major plastics manufacturers involved in the construction of regional polystyrene recycling plants.

We're encouraging the start-up of new recycling efforts, helping to find better ways to collect and sort recyclables, and supporting efforts to create new markets for products made from recycled products.

At Amoco Chemical, we believe recycling can add years of life to our landfills while it transforms things that would ordinarily be thrown away into useful new products. We've only begun to uncover its benefits.

For a free copy of "Recycling. Do It Today For Tomorrow," call 1-800-727-0017. Or write Amoco Chemical, Recycling, 200 E. Randolph Dr., Chicago, IL 60601.

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AMOCO

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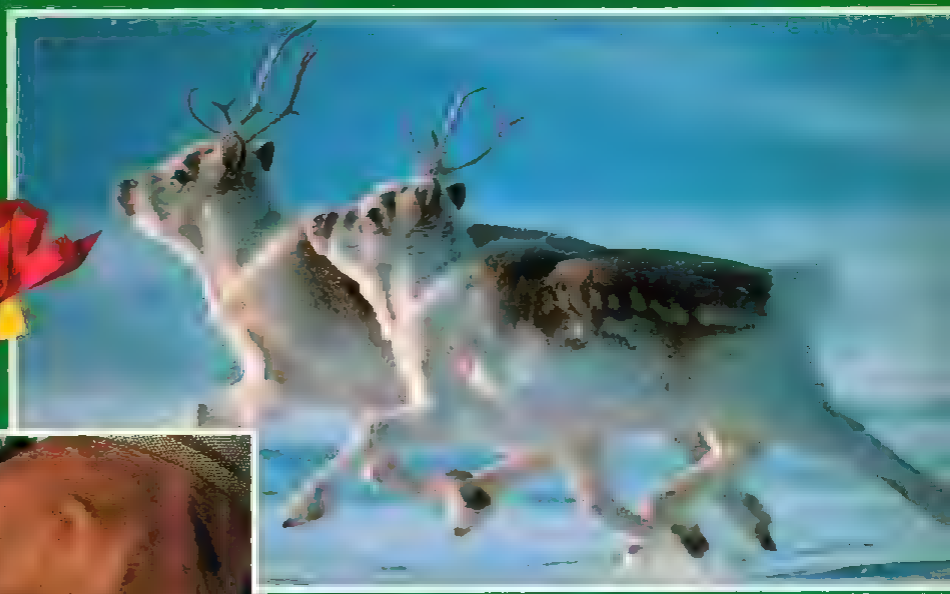
This Christmas give the spirit of the season!



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SNOWY OWLS

BY KATSUMI ITO

Breathtaking realism in fine bisque porcelain, meticulously painted by hand.

Only a privileged few will ever see it in the wild...a pair of majestic *Snowy Owls* gently nurturing their young in the nest. Now, gifted wildlife sculptor Katsumi Ito has brought this endearing moment brilliantly to life in fine bisque porcelain.

True-to-nature realism.

Each of the four owls in this magnificent sculpture is painstakingly hand-painted with extraordinary care and precision. The exquisitely sculptured feathers, mysterious yellow eyes, and subtle shading of colors are incredibly realistic.

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OCTOBER 1990

GEOGRAPHICA

NATIONAL GEOGRAPHIC MAGAZINE

Detecting Lightning's Early Warning Signals

Lightning is one of nature's most common, and fearsome, forces. Each day some 45,000 thunderstorms occur worldwide, bringing as many as a hundred lightning strikes every second. In the United States alone lightning killed 74 people and injured 282 in 1989.

The origin of lightning is generally understood (NATIONAL GEOGRAPHIC, June 1950), but the phenomenon itself remains unpredictable. New technology has begun decoding its secrets. The State University of New York (SUNY) at Albany, the Bureau of Land Management, and the National Severe Storms Laboratory have established a network of lightning detectors across the continental U. S. to record lightning bolts that strike the ground. The network also can help locate thunderstorms inside large cloud formations and determine a storm's strength.

"From that, you can tailor more specific warnings to the public," says Steve Harned, a meteorologist with the National Weather Service.

An even better picture of lightning formation and behavior should emerge later this decade from a proposed satellite sensor. It will monitor lightning flashes—perhaps 80 percent of the total—that don't reach the ground.

"Today we're picking up only 20 to 30 percent of all lightning," says Henry Newhouse, the meteorologist coordinating the government's lightning-detection program. "We'll be able to see close to 100 percent with a satellite-based detector. It will be the first time we'll be able to view lightning patterns across the entire continent."

MIKHAIL PIERCE

Fire Spares Freed Golden Lion Tamarins

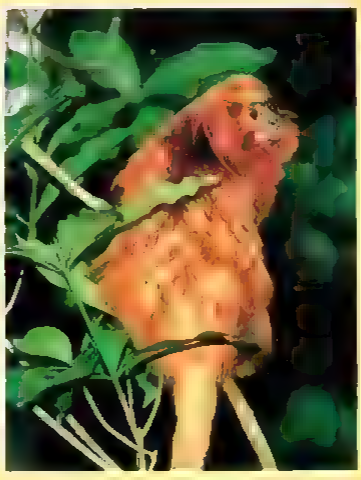
A fire raging in Brazil's Poço das Antas Biological Reserve in February threatened a novel attempt to save a species facing extinction: the introduction into the wild of captive-born monkeys known as golden lion tamarins.

The fire apparently did not kill any of the tamarins. But Devra Kleiman of the National Zoo in Washington, D. C., the program's leader, says it hurt the effort by destroying more of the coastal forest, the animals' habitat.

In the early 1980s fewer than 500 tamarins lived in a tiny patch of coastal forest. Kleiman proposed moving tamarins born in zoos into the reserve. They had to be trained to live in the wild before they were freed; some even had to be taught how to peel a banana. The project was supported by several organizations, including the National Geographic Society.

Of the 75 introduced tamarins, 30 survive; some of the earliest now are dying of old age. Another 34 were born to freed monkeys, and of these, 21 survive. "So we have 51 more animals in the wild as a result of the program," Kleiman says. "It's time-consuming and expensive, but it can be done."

The program includes a major attempt to educate residents of the area about the monkeys' precarious status and the need for reforestation to expand the tamarins' habitat.



IAN YEOMANS

An Eyewitness View of a Maya Ruler

When George Stuart, National Geographic staff archaeologist, first saw the four faded sheets of paper that a colleague had obtained from a Mexico City bookseller years before, they appeared to be blank. But the colleague had transcribed portions when some of the writing was still visible. Stuart was excited: The document dealt with Can Ek, last ruler of the Maya capital of Tayasal, which surrendered to the Spanish in 1697.

Stuart took the pages to Society headquarters, where Al Yee, manager of photographic services, had them photographed under ultraviolet light.

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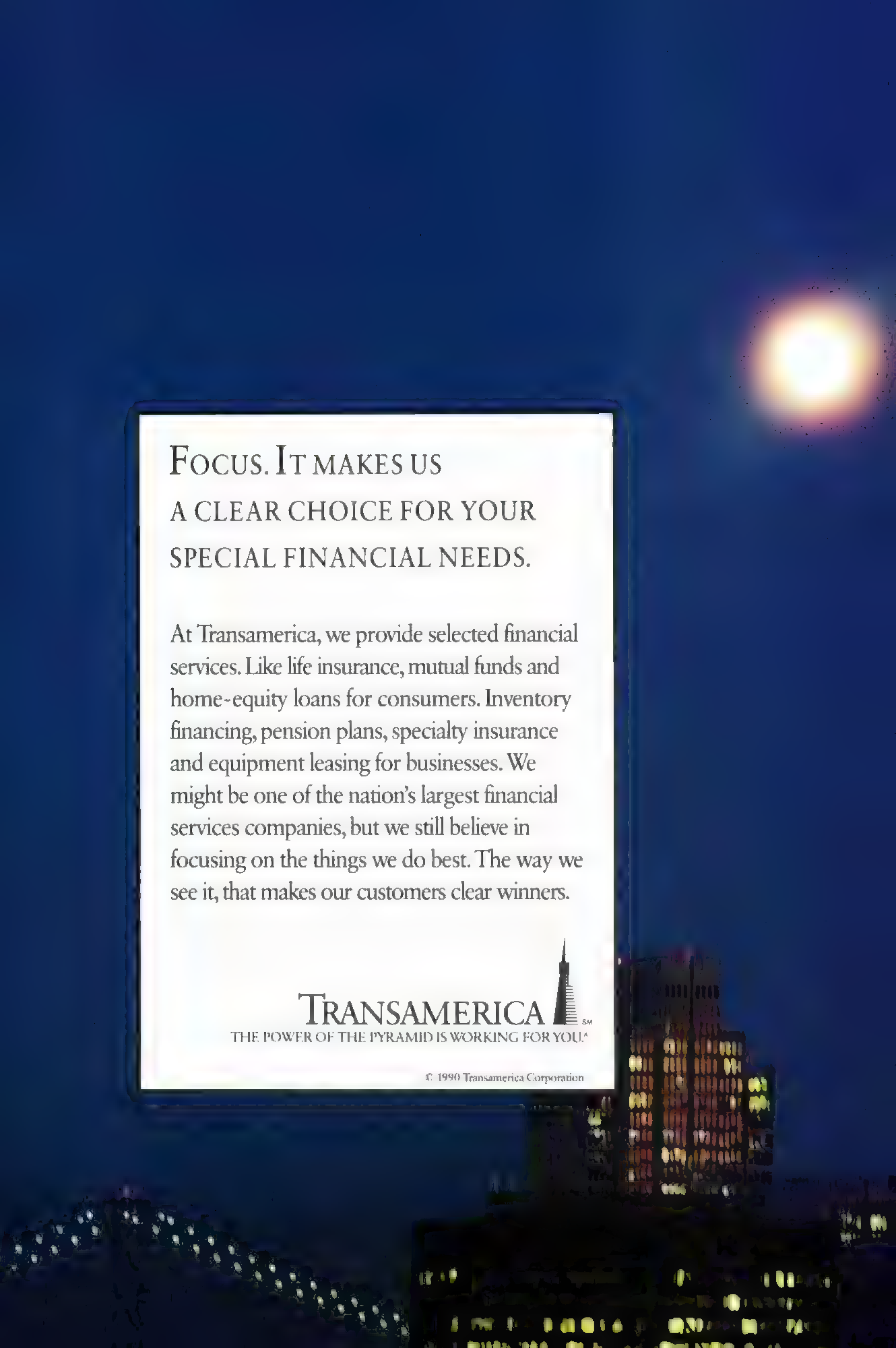
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NATIONAL GEOGRAPHIC PHOTOGRAPHER JOSEPH H. LAVENBURG

The result was a series of prints that revealed the complete text of the four pages. Translated by Grant D. Jones of Davidson College in North Carolina, it contains the first known eyewitness description of a Maya king by a Maya.

Jones says the document, written in broken Spanish by an Indian who accompanied a group of Spanish friars on a visit to Tayasal, in present-day Guatemala, is a fragment of a longer, lost narrative. The text describes a flotilla of flower-covered canoes that greeted the expedition on the shore of Lago Petén Itzá and describes the dress and adornments of Can Ek.

Stuart presented the manuscript, along with photographic prints of the writing, to the Mexican government. Roberto García Moll, director general of Mexico's National Institute of Anthropology and History, accepted the gift at a ceremony in Acapulco.

Mass Extinctions: Not by Meteorite Alone?

Among the best known recent scientific concepts is the theory that a meteorite crashed to earth 66 million years ago, creating a huge dust cloud that blocked out sunlight worldwide and brought about mass extinctions—from small marine species to dinosaurs (GEOGRAPHIC, June 1989).

A Princeton University paleontologist, whose fieldwork was supported by the National Geographic Society, argues that it's not that simple.

Gerta Keller studied the remains of single-celled marine organisms at sites in Tunisia, Spain, Denmark, Israel, and Texas. Keller found that the extinction of many species began some 300,000 years before the 66-million-year-old mark, known as the Cretaceous-Tertiary boundary. And many other species continued to exist hundreds of thousands of years after it, though in reduced numbers.

"It is unlikely that a single catastrophe was the sole cause for the extended period of extinctions," Keller says. She thinks that scientists should consider a range of possible causes—lowering of sea levels, global cooling, increased volcanism—in addition to the meteorite's impact.

Keller believes that environmental changes were responsible for the extinctions before the boundary. "The impact was, perhaps, the last straw or the triggering mechanism to accelerate the whole trend," she speculates.

Witnessing Creation on the "Newest Island"

For more than 25 years Sturla Fridriksson has had a ringside seat at the creation of life. The Icelandic scientist has been recording the arrival, spread, and departure of lifeforms on one of the world's youngest islands: Surtsey, off the southern coast of Iceland. The two-square-kilometer island was born from volcanic eruptions that began in November 1963 (GEOGRAPHIC, May 1965).

Visits to the island are largely restricted to researchers. "Every time scientists go there, they make new discoveries," Fridriksson says.

About 25 species of plants have been recorded on Surtsey, their seeds borne by wind or floating debris, carried by birds, or even attached to fish eggs that float ashore. Some species have failed to take hold, but 18 still grow there, covering between one and two percent of the island. The sea sandwort, which first appeared in 1967, is the most common plant. Six species of seabirds breed on the island.

Fridriksson is modestly proud of his life's work. "I've been there from the beginning," he says. "It's very challenging to have this opportunity."

After a Century, the Name's Still the Game

A stream in the town of Neversink, New York, is named Theodore Gordon Brook, after the father of modern American fly-fishing. A lake along the Marmaton River in Missouri is named Elks Lake—not Round Lake, Sand Lake, or Tucker Lake, as some local residents insist.

Says who? Says the U. S. Board on Geographic Names. Created in 1890 by President Benjamin Harrison to establish standard names and spellings on federal maps, charts, and official documents, the Board on Geographic Names is celebrating its centennial.

ENTERING
Hano
ARIZONA
(NOT HANOKI, HANOM, HA-NO-ME, HANOMUH, HARNO, HARO, IANO, JANO, JANOGUALPA, KOYOSHTU, NA-CA-CHKIN, NAH-SHAH-SHAI, TANO, TANOI, TANOQUEVI, TANOQUIBI, TANOS, TANUS, TEE-WIN-NA, TEHMA, TEWA, TEWA VILLAGE, TEWE, OR TOWAS.)

JEFF MACNELLY

Before it was created, maps carried a bewildering array of names and spellings, often for the same geographic entity. The board's role in standardizing names was considered important enough that its decisions were published in NATIONAL GEOGRAPHIC in the early years of this century. Thus did readers learn in 1904 that a river flowing through Montana and Wyoming—the site of a notable battle 28 years earlier—was the Little Bighorn, not Little Big Horn or Little Horn.

The board gets as many as 20 proposals a month for new names. It tries to follow local usage, but it will not allow places to be named for living persons, nor will it permit names it considers derogatory or transient.

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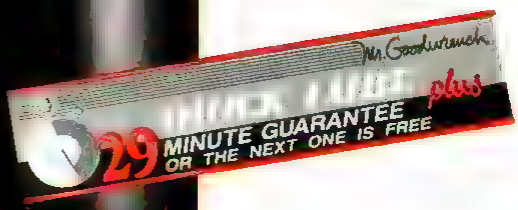

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JIM BRANDENBURG

Wolves in Study Shot, Killed in Minnesota

For scientists studying gray wolves in northern Minnesota, and for the wolves they were studying, last fall's deer-hunting season was a disaster.

At least three gray wolves wearing active radio-transmitter collars were shot and killed in the Minnesota woods during the last week of the hunting season, the U. S. Fish and Wildlife Service reported. A fourth wolf shot was wearing a radio collar that was no longer sending signals.

The gray wolf is listed as threatened in Minnesota and endangered everywhere else in the United States except the state of Alaska.

David Mech, project leader and author of four GEOGRAPHIC articles about wolves, says that about 30 wolves were wearing active radio collars at the time of the shootings. The collars usually transmit for only three years. One of the wolves killed was a female that Mech and his colleagues had been tracking since 1981. Because of the data she had provided, "she was like one in a hundred," he says.

The slain animals were in an area of about 5,000 square miles, and the two wolves closest to each other were more than six miles apart, making it unlikely that any single person had shot more than one, Mech says. One radio-collared wolf was killed in the 1988 deer-hunting season, but none had been lost in the previous three years.

Radio collars are used to provide population data and information on wolf breeding, movement, and behavior within a pack.

Is This the Source of Bronze Age Tin?

When George Bass directed excavation of a Bronze Age shipwreck off Ulu Burun on the Turkish coast (GEOGRAPHIC, December 1987), he and his divers found remains of numerous bronze objects as well as tin ingots. Bronze is an alloy, primarily of copper and tin.

Where did this Bronze Age tin come from? Until now no one has known for sure. The answer may be: almost next door to the wreck site.

K. Ashhan Yener of the Smithsonian Institution has found a tin mine in Turkey's Taurus Mountains dating from between 2900 and 2200 B.C.—about a thousand years before the shipwreck. Yener and her team also found charcoal, pottery sherds, stone tools, and animal bones, indicating that workers may have lived in the mine.

There is a link to the Ulu Burun wreck, Yener says. Analysis shows that lead from the area is identical to lead in net sinkers found on the ship.

"Tin was the major component of this mine, but it also yielded iron, and others in the area had copper, gold, and silver," says Yener. "The whole region contained minerals."

Near the mine, Yener's team has found a major Bronze Age metal processing site with as many as 25,000 stone tools: hammerstones, adzes, axes, pounders, mortars, and pestles, among others. "Early miners may have been processing a whole array of ores and shipping the metal to the coast, about 150 miles away," Yener says. "Ships may have stopped there to pick up cargo."

Footprints on the Trail of the Earliest Humans

Ever since Mary D. Leakey and her team discovered 3.5-million-year-old footprint trails that may have been made by our human ancestors (GEOGRAPHIC, April 1979), debates have raged among scientists. What creatures left their prints in volcanic ash at Laetoli in Tanzania? How "human" were they? What do the prints say about the way these early upright walkers lived?

Russell H. Tuttle, an anthropologist at the University of Chicago, has concluded that the most extensive tracks at Laetoli truly are similar to those of modern humans—those of us, at least, who go barefoot.

Tuttle noted that studies of human gait had been done only on people who wear shoes. So he went to the mountains of Peru and asked 69 Machiguenga Indians, who have never worn shoes, to walk on pressure-sensitive paper so that he could record their footprint impressions.

Tuttle measured their feet, the length and width of their stride, the way they walked from step to step. The result? "Overall," says Tuttle, the Laetoli footprint trails "bear telling resemblances to those of habitually unshod *Homo sapiens*."

JOHN READER, PHOTO RESEARCHERS

One difference is that two of the three Laetoli hominids had a wider stride than the typical Machiguenga. But, says Tuttle, that may be because the early hominids were walking on moist volcanic ash on uneven terrain; the Indians were walking on a level earthen volleyball court.

Suggestions for GEOGRAPHICA may be *submitted to Boris Weintraub*, National Geographic Magazine, Box 37357, Washington, D. C. 20036, and should include the sender's address and telephone number.

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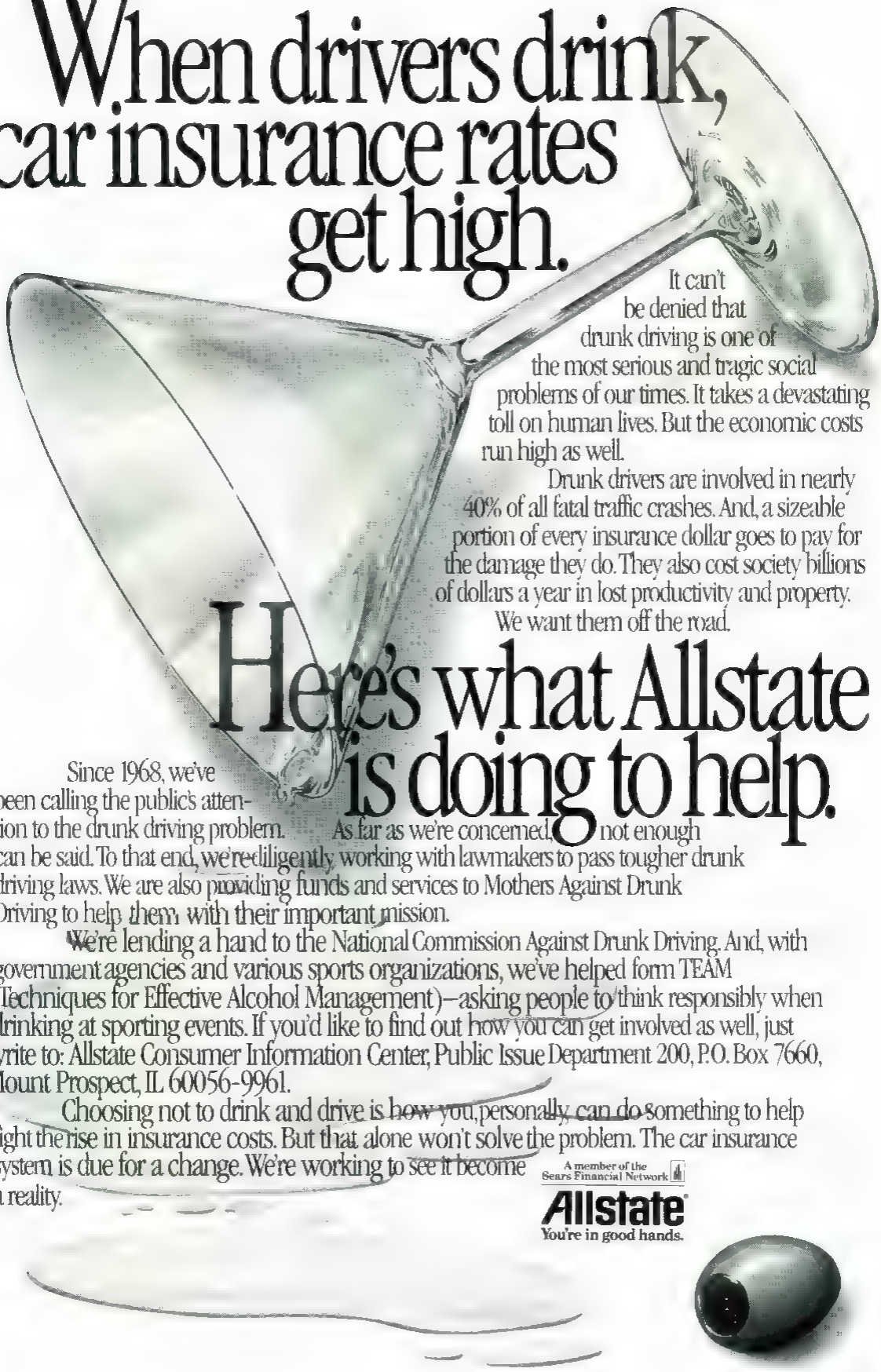

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FROM THE EDITOR

Poor Grade on a Global Test

THIS PAST SUMMER Americans received a report card of sorts on their efforts to improve and protect the world environment. By anyone's standards we failed the course, with a grade of only slightly more than 4 on a scale of 1 to 10.

The report card was issued by a group of some 150 environmental organizations, including the prestigious Environmental Defense Fund, on the occasion of the economic summit in Houston, Texas. The group graded the seven participating nations on their records over the previous year in half a dozen environmental categories. The highest grade we received was 6 for environmental aid to Eastern Europe and for protection of global biodiversity, including such threatened resources as tropical rain forests. On control of ocean pollution we earned a 5.

Italy registered an unenviable 1 in environmental assistance to Third World nations—the lowest grade of any country in any category. As a result, Italy wound up with an overall grade of 3.9 and the worst rating among all seven countries. Japan was the next worst, and the United States was close behind, with an overall grade of 4.15 and a rating of "poor." Canada and the United Kingdom were also rated "poor," while France did slightly better. West Germany led the list with an overall grade of 6.5 and a rating of "good." Next year, however, a reunified Germany could fare much worse, thanks to half a century of environmental destruction in East Germany.

One of the United States' lowest grades was a 3 on the issue of global warming, a complex phenomenon explored in this issue by Senior Assistant Editor Samuel Matthews and photographer James Sugar in their article entitled "Is Our World Warming?" Environmentalists charge that the United States has been slow to recognize the dangers of the so-called greenhouse effect intensified by increased carbon dioxide and other heat-trapping gases in our atmosphere. As a result of that effect on planet earth, Matthews writes, "our one and only home may be in harm's way. . . ."

The best answer for that is to improve our environmental report card.

William Graves

OCTOBER 1990

NATIONAL GEOGRAPHIC

HYDROID ON A HERMIT CRAB

CAJUN TWO-STEP

ELUSIVE GREEN FLASH AT SUNSET

DOGON DIVINER WORKS IN SAND

RAFT ON A HOT GREEN ROOF

Japan's Suruga Bay 2

In the shadow of Mount Fuji, a little-explored harbor holds an amazing array of sea life. Using the latest underwater technology, photographers David Doubilet and Emory Kristof and marine biologist Eugenie Clark plumb its mysteries to depths of 7,000 feet.

The Cajuns: Still Loving Life 40

With a history of exile and exclusion stretching back to the 1750s, these descendants of Nova Scotia's Acadians have developed a unique and enduring culture in south Louisiana. Today they watch with amusement as their spicy folkways are commercialized from New York to San Francisco as "Cajun chic." Griffin Smith, Jr., and photographer William Albert Allard capture their joie de vivre.

Is Our World Warming? 66

Earth's atmosphere isn't what it was a hundred years ago: Carbon dioxide—up by 25 percent—methane, CFCs, and other gases are adding to the greenhouse effect. Is global temperature rising as a result? How will our long-term climate be affected? Samuel W. Matthews seeks answers to these urgent questions. Photographs by James A. Sugar.

Mali's Dogon People 100

In the unyielding landscape of Africa's Sahel, the Dogon guard the rituals that have sustained them for centuries. Carrying their dead high into the cliffs, they reverently reuse the burial caves of an earlier people. By David Roberts, with photographs by José Azel.

A Raft Atop the Rain Forest 129

Lowered by dirigible onto the tropical canopy of French Guiana, a huge raft offers an international team of scientists an unprecedented bird's-eye view of the diverse life in a vanishing realm. Team leader Francis Hallé reports, with photographs by Raphael Gaillarde.

COVER: *Delicate but deadly, a juvenile lionfish, little larger than a silver dollar, sports both venomous spines and elongated pectoral fins that sweep prey into its path. Photographed in Suruga Bay by David Doubilet.*

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駿河湾

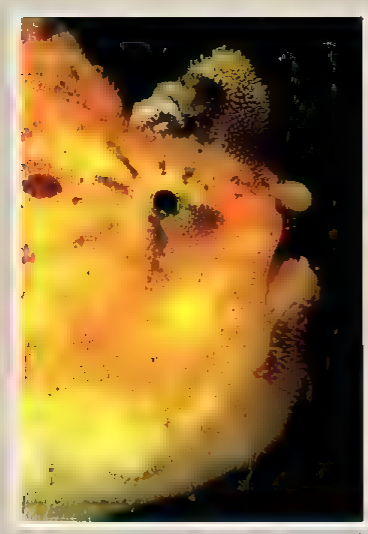
SURUGA BAY

Photographs by DAVID DOUBILET and EMORY KRISTOF
NATIONAL GEOGRAPHIC PHOTOGRAPHER

Introduction by DAVID DOUBILET

In the Shadow of Mount Fuji

THE SNOW-COVERED TOP of Mount Fuji mirrors the Japanese dawn. As it catches the sun's first light, Fuji's summit turns from lacquer red to rose. In the shadows below, the mountain's huge sloping shoulders and base remain dimly outlined in predawn gray. Far below, the waters of Suruga Bay are cloaked in deepest black.



FROGFISH (*ANTENNARIUS STRIATUS*)

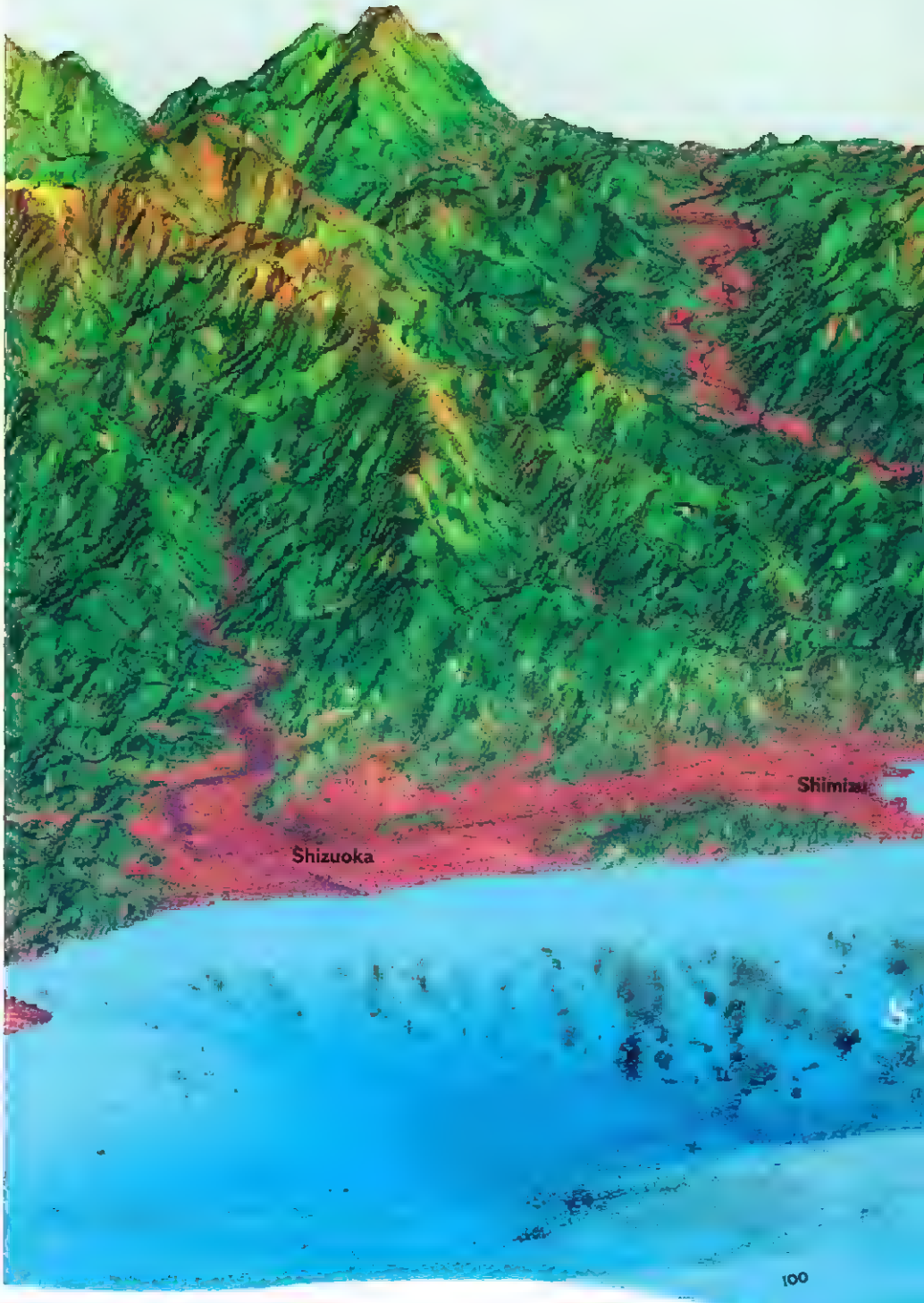
To the Japanese who awake each day in the cool shadows of Mount Fuji, the volcanic cone and the brooding bay at its foot form a kind of mystical partnership. The upper slopes of the mountain hold the bright promise of gods; Suruga Bay, dark and forbidding, is the realm of demons.

Suruga Bay is about 40 miles long and 15 to 35 miles wide, bordered on the north by Mount Fuji and on the east by the mountainous Izu Peninsula. What makes it special is its extraordinary depth—plunging to more than 8,000 feet a few miles offshore—and the deep-sea creatures that live there.

I have sometimes imagined that the deep ocean sends arteries reaching upward toward Japan, pumping life into the shallow waters along her shores. The deep troughs of Suruga Bay and the Sagami Sea on the eastern side of the Izu Peninsula feed into two different Pacific trenches. The canyon of Suruga Bay dives southward into the dark chasm of the Nankai Trough, some 16,000 feet deep. Suruga Bay is, in a sense, an extension of the distant deep ocean, an alcove of the abyss. For nearly a decade I have dreamed of exploring it. *(Continued on page 8)*

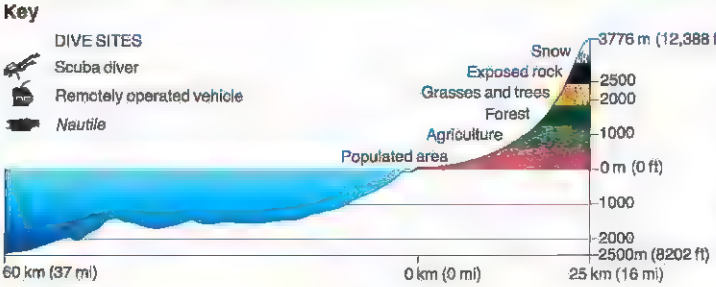
Under the great mass of Mount Fuji, Japan's deepest bay plunges toward abyssal depths. A bifocal view captures the robot SeaROVER in waters that, although fished for thousands of years, still remain little explored.

DAVID DOUBILET (LEFT) AND WITH KENJI YAMAGUCHI, NGS STAFF (RIGHT)



Key

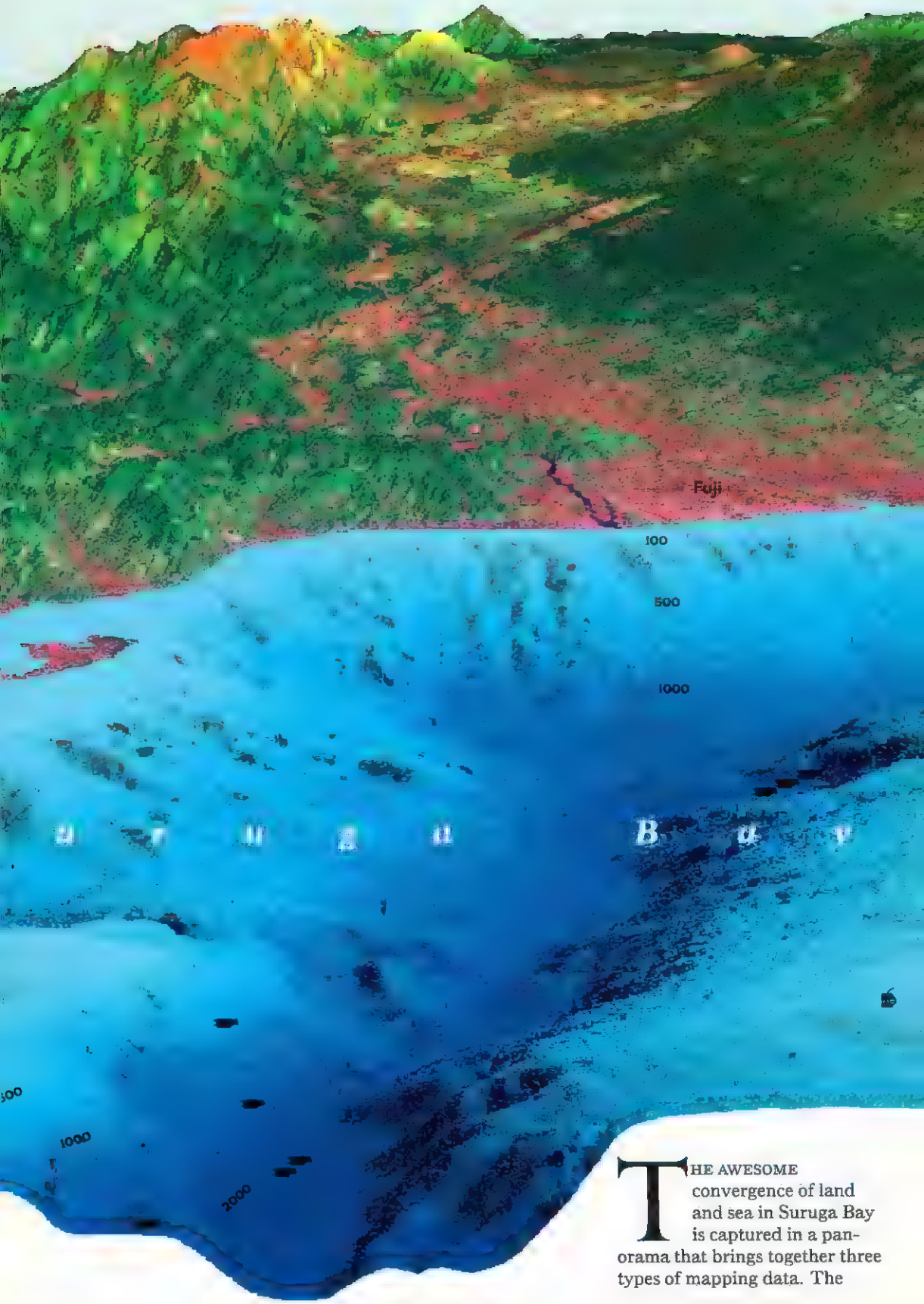
DIVE SITES
Scuba diver
Remotely operated vehicle
Nautile



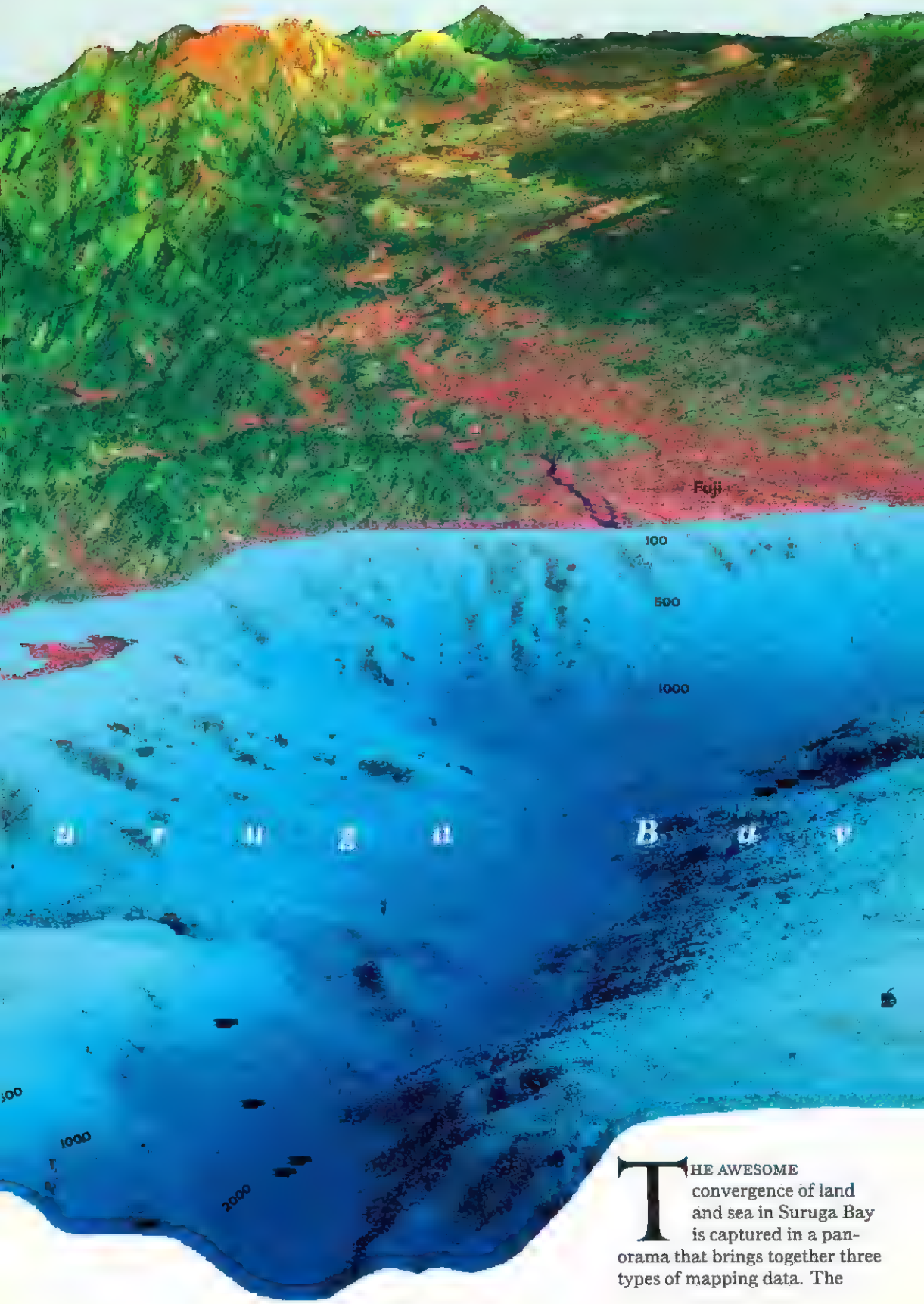
Soundings in meters

Scale varies in this perspective (above).

CREATED FOR NATIONAL GEOGRAPHIC MAGAZINE BY GEOGRAPHICAL SURVEY INSTITUTE, TSUKUBA, JAPAN; BATHYMETRY COURTESY OF MARITIME SAFETY AGENCY, HYDROGRAPHIC DEPARTMENT, TOKYO, JAPAN



THE AWESOME convergence of land and sea in Suruga Bay is captured in a panorama that brings together three types of mapping data. The



THE AWESOME convergence of land and sea in Suruga Bay is captured in a panorama that brings together three types of mapping data. The

sophisticated merger began when sea depth measurements were joined to land elevation data to create a three-dimensional computer model. The model was then matched with satellite images taken by Landsat 5. Water depths were color-coded by computer.

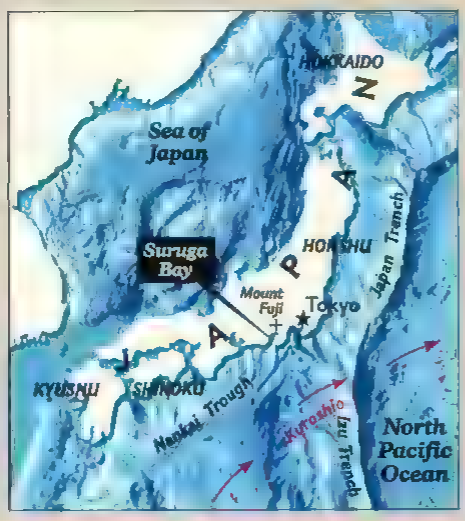
The very symbol of Japan, Mount Fuji reigns over the bay. Urban corridors support industries such as chemical production and fish processing, as well as tea fields, paddies, orchards, and mulberries for silkworms. Freighters dock at Shimizu, the bay's largest port.

There are many kinds of dreams, and diving dreams are vastly different from mountain climbing dreams or even space dreams—you don't see upward toward a goal or a peak or a distant star. You look down into darkness, into a place where imagination has no footholds.

My dream was born while diving in the waters of the Sagami Sea, Suruga's neighbor. I had dived to what I consider my safe working limit—180 feet—and hung motionless above a steeply sloping seafloor in a bizarre orchard of white soft coral trees. A blotchy swell shark with bright green emerald eyes slowly swam through the trees, then disappeared down the shelf into blackness.

That shark was on a journey to a place in the oceans I call the middle depths, the waters from 180 to 2,500 feet deep—beyond the range of scuba divers and yet far above the abyssal seafloor.

"Suruga Bay is, in a sense, an extension of the distant deep ocean, an alcove of the abyss."



The middle depths, especially off central Japan, are a hidden oasis of life, fed by nutrients eroded from the surrounding mountains or pumped in by the Kuroshio current, Japan's equivalent of the Atlantic Ocean's Gulf Stream, which rubs against the Japanese coast as it heads northeast toward the Aleutians.

It was into this world at the edge of light—and the deeper world below—that the swell shark had passed. I longed to follow.

I discovered I was not alone in this dream. It was shared by others, including my longtime colleagues, marine biologist Eugenie Clark and National Geographic photographer Emory Kristof.

Back then, however, our dream was fathoms beyond reality. It has only been in the past ten years that Emory and Chris Nicholson, an inventor and the president of Deep Sea Systems, have developed the technology to "fish" for images in the deep sea. Today our fishing gear includes underwater robot cameras and research submersibles rigged with wide-angle, deepwater optics and sophisticated electronics—much of it developed by the late Alvin M. Chandler of National Geographic. It was Chandler's vision and almost sculptural engineering of equipment that opened our modern photographic window on the deep sea.

In 1989 my friend Koji Nakamura, an extraordinary Japanese diver and underwater cameraman, put together a plan that involved the National Geographic Society, Tokyo Broadcasting System, and the Toba Aquarium. In the autumn Emory, Genie Clark, and I met Koji and his crew at the edge of Suruga Bay to do some extraordinary fishing.

With ten long years to think about it, Emory and I had devised a highly scientific strategy for covering Suruga Bay: We divided it up like Chicago gangsters of the 1920s.

Using scuba gear, I would make pictures down to about 180 feet. Below that, Emory was in charge. From 180 to 800 feet, he and his crew used two remotely operated vehicles (ROVs), small robots with mechanical arms, television eyes, and deepwater cameras. For depths below 800 feet, Emory and Genie dived in the French submersible *Nautile,* which was contracted from the French Research Institute for Exploitation

of the Sea and equipped with National Geographic's special deepwater cameras.

We based ourselves on the western side of the Izu Peninsula. Emory's ROV and submersible team worked out of the fishing port of Heda. My shallow-water diving team worked from the seaside resort of Osezaki, four miles north.

Diving in Japan is no simple matter. Every few miles along the Japanese coast sits a fishing village with a concrete wharf, a breakwater, and dozens of fishing boats. The fish in each section of the sea, and each part of the coastline, belong to specific fishermen's associations. There are, in essence, invisible lines and fences in the sea, every bit as real as the invisible fences around a Japanese rice field. For us to anchor a boat and plunge in would be perceived as trespassing.

"Japanese fishermen are very jealous of their sea," Koji explained. "Legally the sea belongs to all people, but everything in Japan is done by consensus. So fishermen control the divers. For example, we can't dive at night because the fishermen think we scare the lobsters."

The fishermen's association at Heda was different. Men from the Izu Peninsula have been fishing the depths of Suruga Bay for thousands of years and wondering all that time, it seems, about the bizarre deep-sea creatures that flopped on the decks of their fishing boats. Unlike local shallow-water fishermen, who know every stone and shoal in the waters they fish, these deepwater fishermen wanted to know more about the world their creatures lived in. They were so curious, in fact, that they helped arrange for a boat, a 130-foot fishing vessel named *Daishi Maru*, to assist Emory with the ROVs.

Osezaki, on the other hand, is not a fishing town but a diving resort, one of only a few on the Suruga side of the Izu Peninsula. It faces a classic curving bay protected by a small pine-covered peninsula. Along its beach half a dozen hotels and pensions cater exclusively to scuba divers, who are allowed to explore a small underwater park set aside for diving.

During the week Osezaki is deserted, but on weekends as many as 700 scuba divers from Tokyo descend on it, clad in flashy diving suits that light up the beach with every color in the visible spectrum, including the currently fashionable combination of lime green and aircraft orange. Each Saturday morning they make for the water en masse, like high-tech lemmings.

Fortunately, this vast hoard of divers does not seem to upset the balance of nature. By Monday, I knew, peace would again filter down through the waters of Suruga Bay. The clouds of muck stirred up by a thousand swim fins would slowly clear, and delicate sand creatures would emerge from their hiding places. We would wait to dive until then.

With perfect luck, Monday dawned cold and miserable. And then the dark clouds came, and then it began to rain.

FOR DAYS MOUNT FUJI seemed an invisible presence. The sky was gray, overcast. It would rain hard, then drizzle, and then mist would cover the sea and steam across the surface.

Early one morning, about an hour before dawn, the wind shifted to the west and the sky cleared. I stood on the balcony of my hotel and watched the play of light on Fuji's summit.

Later that morning we entered Suruga Bay. The surface water was slightly murky from the rain, but the sunlight—sunlight we had not seen in days—filled the sea and erased the gloom. My crew and I gathered underwater, checked our equipment—pressure gauges, watches, and diving computers—and tightened our weight belts. I selected the four cameras I would take to the deep, caching others along with extra air tanks.

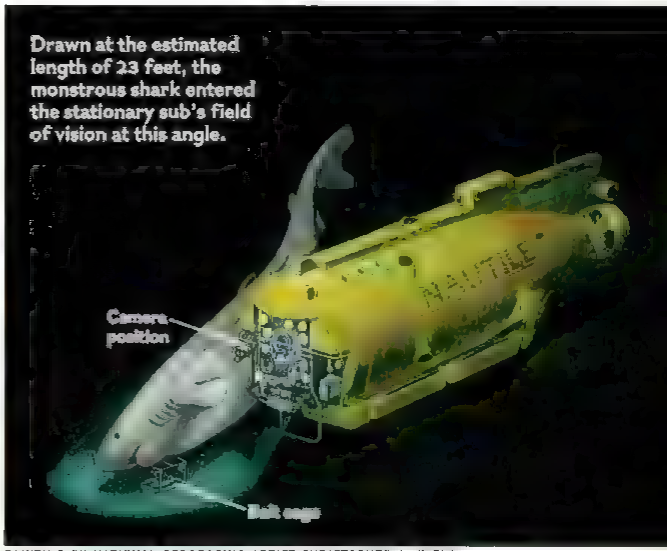
We nodded to each other. Lead diver Tadahiko Matsui pointed ahead, then gestured once with the flat side of his hand, and flew off down the sand slope, kicking, finning, descending like a mountain climber in reverse into a darker land.

The last I saw of the surface world was a view of Mount Fuji, bright and strong against a hard, blue autumn sky. I saw this from water level, and then my eyes dipped below the curtain of the surface into a realm that most people can only imagine.

RALPH WHITE, TOKYO BROADCASTING SYSTEM

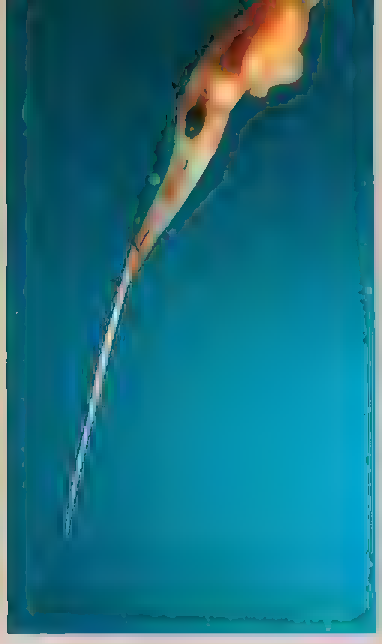
THE LARGEST CREATURE ever seen in the deep sea lumbered in front of the view ports of the submersible *Nautile* on September 13, 1989. Four thousand feet deep, the Pacific sleeper shark, *Somniosus pacificus,* crashed into the two-by-two-foot bait cage and pushed it into the mud. Because of the angle of the shark's approach, the men inside *Nautile* were unable to see the entire body (painting). "The best we can say is that it was more than 23 feet long," says shark expert Eugenie Clark, chief scientist of the Suruga Bay expedition.

For the three eyewitnesses inside the 26-foot-long sub—pilot Jean-Michel Nivagglio, copilot André Bonfiglio, and cameraman Ralph White—the encounter began soon after they


Drawn at the estimated length of 23 feet, the monstrous shark entered the stationary sub's field of vision at this angle.
Camera position
Bait cage

PAINTING BY NATIONAL GEOGRAPHIC ARTIST CHRISTOPHER A. KLEIN

had completed their 30-minute descent. White recalls: "We saw a fish bump into a wall, and then the wall moved. The sub shook. On the shark's second pass we saw the head. Parasites hung from fluttering gills. As it left, we saw enough of the underside to determine it was female. All we could think was holy mackerel!"



Dispatches from a distant world

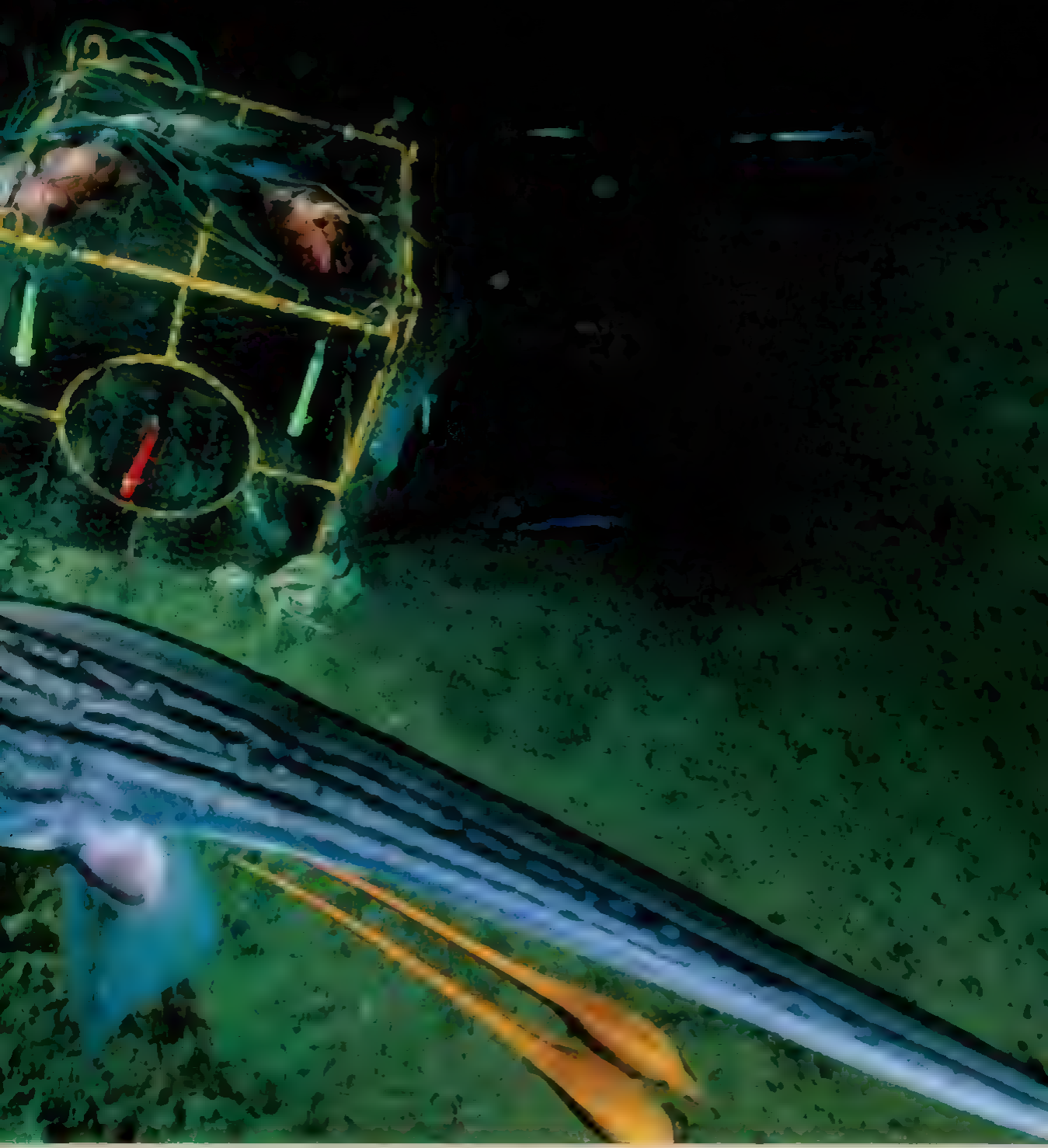
By EUGENIE CLARK

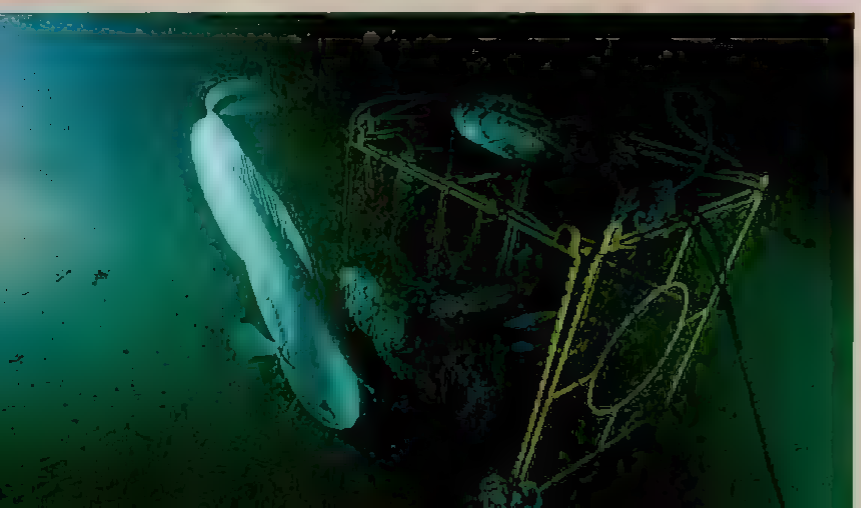
IT WAS AS STARTLING as a splash of blood, a scarlet splotch on a sandy ledge 2,000 feet deep in Suruga Bay. I was surfacing from a dive in the three-person submersible *Nautile*. As we approached the blob, it lifted slightly and glided over the ledge without leaving a trail. Picking up speed, it shot into open water and elongated into a streamlined missile I recognized as a squid (above). About 15 inches long, it swam upward with tentacles down, rippling its mantle like a flamenco dancer.

The deep-dwelling creatures of Suruga Bay have been studied mainly as dead specimens hooked or netted by fishermen. My fellow marine biologists Kiyoshi Suzuki and Kazunari Yano and I wanted to see them alive and in their world. Their world was now outside my window.

Trailing twin egg cases—a phenomenon never before seen in deep natural habitat—a chimaera swam by at 1,450 feet (above). Slowly flapping her fins, she seemed like a bird in flight burdened with prey. Once released, the yolk-rich cases feed the young for as long as a year. The Japanese call this chimaera *ginzame*, silver shark. Like those distant relatives, chimaeras have skeletons of cartilage, not bone. The many chimaeras attracted by our tuna bait often bumped into the cage. They may have been blinded by our sub, their large eyes accustomed only to the dim glow of bioluminescent creatures, such as the tiny lantern sharks that feasted wildly on the bait.

MASTIGOTEUTHIS CORDIFORMIS, RALPH WHITE (TOP LEFT); *CHIMAERA PHANTASMA* AND *ETMOPTERUS MOLLERI* (LANTERN SHARK), EMORY KRISTOF





On the deepest dive, 7,000 feet, an abyssal cusk eel (left) danced in slow motion with the grace of a phantom. Not a true eel, it has long pelvic fins, which help it find food. As with many of the species recorded in Suruga's depths, little is known about this fish. But its scientific name is as regal as its demeanor: *Spectrunculus grandis*.

RALPH WHITE

THE QUESTION MARKS of Suruga Bay exist not only in the depths we explored in *Nautile* but also in the middle kingdom, that realm below 180 feet where scuba divers cannot safely venture. Given the expense of using manned submersibles, scientists have tended to pass through this zone in their hurry to study the bottom. Only in recent years has this niche been examined by a new generation of unmanned remotely operated vehicles. Using video and still cameras, ROVs transmit live video images through a tether to the mother ship, allowing scientists to be, in a way, armchair explorers.

Like human divers ROVs work well in pairs, assisting each other with lighting and tricky maneuvering. We saw Suruga Bay through the eyes of MiniROVER and National Geographic's SeaROVER, both designed by Chris Nicholson of Deep Sea Systems. Chris and assistants Jeff Ledda and Marshall Flake operated MiniROVER; photographer Emory Kristof led the Geographic team of Michael Cole, Keith Moorehead, and Kenji Yamaguchi. Seated in front of video screens in the hull of *Daishi Maru*, the Japanese fishing vessel, we shared the experience of diving as deep as 800 feet.

Anchored on rock at 225 feet, a three-foot-tall soft coral, *Dendronephthya gigantea* (right), extends to its full height to feed at night on plankton. The surrounding menagerie of invertebrates follows the drape of ■ fishing net snagged here years ago.

Sixteen handsome dragonet species live in the bay. A female *Foetorepus altivelis* stood her ground at 450 feet (bottom right). She hoisted her sail-like dorsal fin in what may well have been an aggressive response to the ROVs' intrusion.

Fish react variously to ROVs. Emory jokes that some confront the robots with a posture that says, "I know I'm lunch." But many are drawn to the lights. At 450 feet, ■ five-inch-long snipefish, *Macrorhamphosus scolopax*, broke ranks with a school we had been observing—and risked being eaten—when it followed SeaROVER to ■ bottom-dwelling rockfish (left). Also called a rockcod or scorpionfish, this rockfish is a member of the genus *Sebastiscus*.

On the other side of the Pacific, related species of these fish played parts in a cautionary tale of marine biology. When a snipefish was recovered from the belly of a rockfish off Santa Monica in 1962, it was the first found in California waters since 1920. Then in 1967 purse seiners looking for mackerel accidentally found two schools of the supposedly rare snipefish that numbered 15 million individuals. The fish had always been there, in the depths. But their numbers could not be revealed by what was then the state-of-the-art method of collecting: dipnetting specimens drawn to the surface by a spotlight.

ALL BY EMORY KRISTOF, MICHAEL COLE, AND KEITH A. MOOREHEAD, ALL NGS STAFF

Suruga Bay

A FIGURE out of *War of the Worlds* loomed in the lights of MiniROVER at 450 feet. Dwarfing all other crustaceans, the giant spider crab has been known to attain a claw span of 12 feet. When viewed head-on, with MiniROVER hovering, the female adult appeared to

measure about six feet across. *Macrocheira kaempferi* lives solely on Japan's Pacific coast at depths as great as 1,200 feet, eating mollusks, fish, and smaller crustaceans. Known to feed on the bodies of drowned humans, it has been called *shinin gani*—dead man's crab. When the ROVs passed over a fisherman's boot and then its mate and a pair of overalls, we wondered if shinin gani had been at work. But a check with the Suruga Bay fishermen's association revealed no recent losses.

Human predation on the giant spider crab, however, threatens its numbers. It matures slowly, taking about ten years to reach mating age. But it is the sweet-fleshed young crabs for which fishermen set their traps, and that harvest means fewer survive to reproduce. Those who avoid traps may live more than 50 years.

BOTH BY EMORY KRISTOF, MICHAEL COLE, AND KEITH A. MOOREHEAD

ALL BY EMORY KRISTOF, MICHAEL COLE, AND KEITH A. MOOREHEAD

A QUICKSILVER FLASH, a cutlass fish mesmerized us with its hyperkinetic behavior at 750 feet (above). Creatures of the deep tend to move slowly to conserve energy. *Benthodesmus tenuis*, said Emory Kristof, "seemed to be going 90 miles an hour." How to capture this speedster on film? SeaROVER's single-lens-reflex camera, designed by National Geographic staff member Joe Stancampiano, is the first that allows closeup photographs to be composed and focused remotely.

Using that camera, as well as the ROV's wide-angle lens, requires the coordinated efforts of Kristof and the SeaROVER pilots, Keith Moorehead and Michael Cole. Emory pushes the shutter as the photographer, but all three create the picture. It is challenging even under the best of conditions.

The cutlass fish stakeout began by focusing on a cerianthid, a tube anemone. When the fish darted by, the crew was able to catch at least its head. "And that was pure luck," says Emory. "We could just as easily have gotten only the tail."

The patch on top of the fish's head is a pineal window, a small transparent area of skin often found on fish that live in the twilight zone—the depths that still receive sunlight but not enough, for instance, to allow plant photosynthesis. In Suruga Bay this zone runs from about 550 to 2,500 feet. Day can barely be distinguished from night. But the window allows light to reach the pineal organ in the brain, alerting deep dwellers that it is day. At night, when most animals ascend in the water column to feed, lack of light stimulation tells residents of the twilight zone that it's time to rise. The cutlass fish was photographed at night; we never saw the species at that depth during the day.

An unknown factor: What effect might ROV lights have had on the fish? Certainly many sea creatures are attracted by bright light, but some seem to go crazy in its presence, berserkly tumbling and zigzagging. Ichthyologist Charles Breder, my first mentor, called this phenomenon "locomotor disorganization." He was studying fish in a darkened

aquarium, and it seemed likely that we too would observe this behavior in the twilight zone, where bright light is utterly foreign. Perhaps that was a factor on one night dive at 450 feet when a school of bristlemouths dancing in front of SeaROVER's lights became a meal for a moray eel (series at right), one of ten species in the bay. The fish were drawn by the lights, and the eel by the fish. It was, said Emory, "as if someone hung out a sign saying Eat Here."

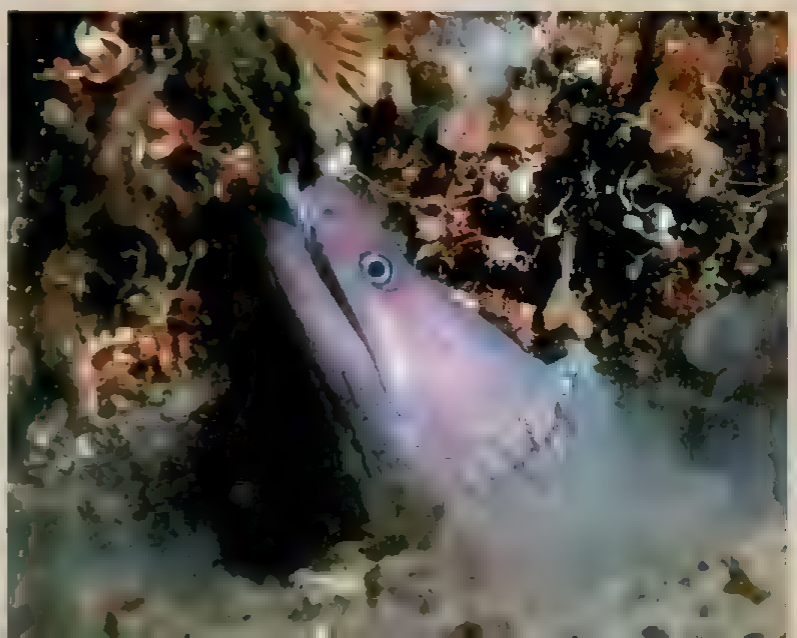
Like cutlass fish, bristlemouths also have pineal windows. Another of their deepwater adaptations is a row of bioluminescent lights along the belly. In the dim deep, predators often hunt by looking up to detect the silhouettes of prey. A bristlemouth can disguise its silhouette by adjusting the belly lights to match the intensity of the ambient light—a level it is able to judge because of its pineal organ.

Another moray attacked SeaROVER but couldn't get a bite on the robot. Turning to nearby MiniROVER, the eel charged and nearly knocked itself out on the dome. Its retreat was wobbly.

Collecting and displaying live deepwater specimens has been an elusive goal for aquariums. ROVs offer new opportunities for collecting, but the problems of pressure, temperature, and light conditions still remain. Yet ROVs may help here also, by taping 3-D videos of the animals in their natural habitats. In Suruga Bay, two TV cameras on MiniROVER took the first underwater 3-D videos, scheduled to be shown at the Toba Aquarium located on a peninsula west of the bay. Emory developed this concept, which he calls a "dry aquarium." It's a vital introduction to inhabitants of our planet that we are just beginning to understand.

Suruga Bay

GYMNOTHORAX SP. (EEL); *MAUROLICUS MUELLERI* (BRISTLEMOUTH)



Dreams and nightmares in Suruga's wire coral forest

Text and photographs by DAVID DOUBILET

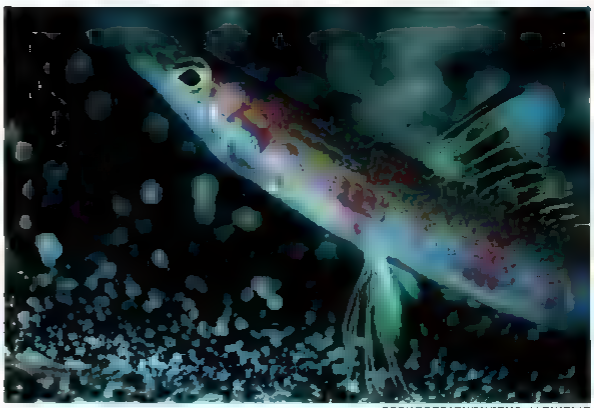
WE WENT DEEP on our first dive at Osezaki. At 120 feet we left the sand slope and entered a coral forest, edging down toward 180. Strands of wire coral, a type

CIRRHIPATHES SP. (BLACK CORAL); *APOGON* SP. (CARDINAL FISH)

of black coral, twisted upward from every rock, polyps open, feeding in the green sea. It was a very strange part of the ocean.

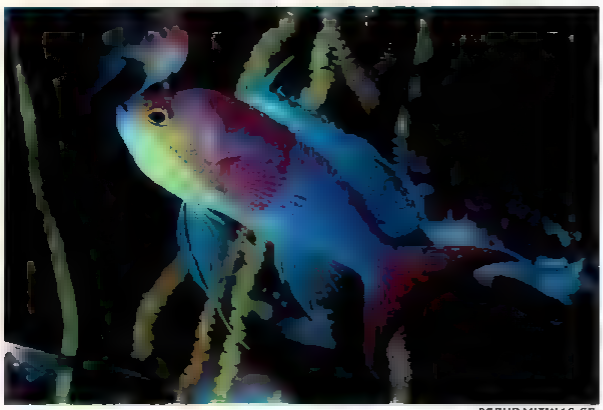
It was to get even stranger. At this depth nitrogen accumulates in the bloodstream and has a narcotic effect on the brain. The bizarre scene began to slide from deep reality into hallucination: The light of my partner, Nikolas Konstantinou, became a pale blue headlamp on a foggy mountain road. A passing school of cardinal fish turned into an artist's palette. Niki and I were lost children in a fairy tale, roaming through a witch's scalp.

WITHIN THE STRANDS of the wire coral forest, schools of three-inch-long cardinal fish hovered facing into the current, their silvery skins mirroring the camera's electronic flash. A large male cherry-blossom anthias, found mainly in Japanese waters, floated before the rippling silver curtain like a resplendent Kabuki actor, parading on a moonlit stage.



PSEUDOTRICHONOTUS ALTIVELIS

SACURA MARGARITACEA



PSEUDANTHIAS SP.

Another anthias (left), clothed in deepwater finery, sifted through the strands of wire coral for plankton, while a tripod lizard fish (far left) rested on its pelvic fins. Pushing up and forward with these fins, the fish can literally blast off from the sand bottom to catch drifting plankton. It can also use the fins as a tripod while it probes for creatures on the seafloor with its long slender snout.

MEMORY beneath the sea has a short life span. We drifted upward, and our wire coral fantasies vanished in the green mist beneath our fins. The numbing effect of nitrogen narcosis also disappeared. Suddenly I was clearheaded, as if awakened from a dream.

Yet some nitrogen remained in our bloodstreams. To avoid the bends, we would have to decompress, lingering on our way to the surface.

On the gentle sand slopes near our stash of extra air tanks and cameras, Niki found the most jewel-like, exquisite fish I'd ever seen—a juvenile lionfish, *Pterois volitans,* the size of a silver dollar (right), fluttering in midwater like a butterfly. I approached it with care because for all its delicacy its venomous

spines appeared to be in perfect working order.

Lionfish may look fragile, but they most definitely are not. They use their wings to herd prey—small invertebrates and other fish—into position to devour them. Later our colleague Tadahiko Matsui found an even smaller *Pterois*. It settled in his glove and opened and closed its wings like a geisha's fan.

MOUNT FUJI last erupted in 1707, spewing hot ash over Suruga Bay. For weeks black ash fell like rain, settling to the bottom and coating the sand with yet another layer of volcanic cinders.

As we examined this soft blanket, I realized that it was a rich soil filled with life. Between the grains lay a world of tiny crustaceans and other creatures thriving in the oxygen-rich space between particles. Sand, I knew, was also a place of death, ruled by monsters.

At the edge of my vision I saw movement. A small eel's head emerged, peered around, then ducked out of sight, rippling the sand. It was a species of snake eel I'd never seen before, and I waited 40 minutes for it to reappear. The eel resembled an orange Muppet grandfather, chinless and toothless, with white polka dots and a shifty eye. It gave me a cynical stare, flexed its gummy jaws, then disappeared into the sand.

Another snake eel (below) popped up nearby. This species uses the sand as a hunting blind and burrows through the gritty world like a mole. Its pupils, narrowed to slits, looked like gun ports. Filmy mucus may protect its skin from abrasion. The eel's evil grin is appropriate. It is the tiger, the shark, of the sand world. It preys on other predators and on the fish who make their living gardening for crustaceans in the sand.

APTERICHTUS MOSERI (LEFT); PISODONOPHIS ZOPHISTIUS

PTERELEOTRIS HANAE

CERIANTHUS FILIFORMIS

PALE AND GHOSTLIKE, cerianthids the size of dinner plates live in the soft sand of Osezaki's inner bay. With their tentacles streaming in the current, they resemble flowers swaying in a night wind. But they are not flowers. They are animals, and their tentacles are coated with stinging cells called nematocysts, each with a microscopic harpoon to stun and capture plankton and swimming prey.

Trying to get close to the tube anemones taught me how difficult it is to work along the volcanic sand bottom. A single kick from a flipper, a quick movement of a hand, would generate a swirling sandstorm. Sand would then rain down on the crouching anemone, causing it to retreat into its home buried in the sand. One false move and the beautiful flowering animal would turn into a flesh-colored stump.

Farther up the sand slope, silhouetted against the gloomy afternoon light, I saw a pair of *hanahaze* gobies feeding in open water, using their magnificent lyre-shaped tails to steady themselves.

Eugenie Clark had told me about this species of goby. "They're plankton feeders, not bottom feeders like most gobies," she had said. "But the most interesting thing is that they share their burrow with another pair of gobies and a pair of bulldozer shrimps."

In one of nature's greatest odd-couple acts, the gobies work as seeing-eye fish for the shrimps, which are practically blind, alerting them to the presence of danger. The shrimps in turn keep the burrow clean by sifting and bulldozing for food.

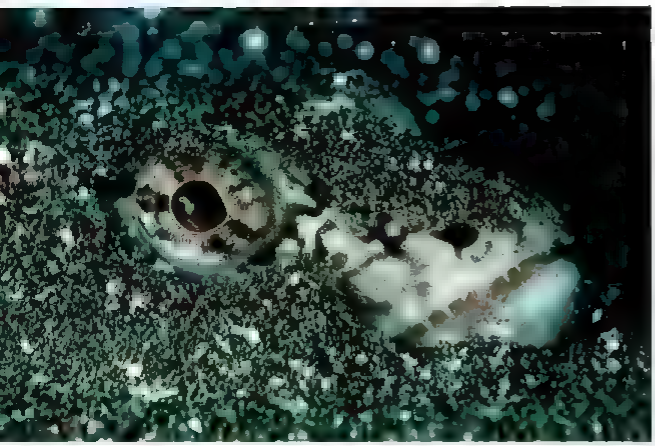
All this makes for quite a household. The four gobies pile in whenever danger threatens, wreaking havoc on the burrow. When danger passes, the hanahazes go back to feeding in the open water above. The other gobies emerge and graze in the sand. And the shrimps are left to clean up after their housemates.

As I approached, one of the gobies dived into the burrow. The other (below left) turned to guard the entrance with a hostile stare. I held perfectly still, breathing as little as possible. But my exhaust bubbles must have sounded murderously roaring to the fish. And I must have looked monstrous, with a huge eye (my mask), two fins, and a plastic howitzer (my camera) equipped with electronic flash. In a world without lightning storms, this must be terrifying.

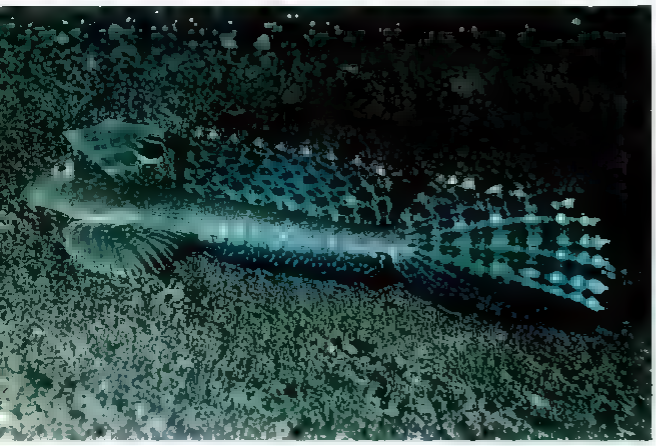
And so I took its picture. The hanahaze flinched and disappeared in a blink.

SAND DWELLERS are masters of invention, and any structure on a sand bottom is worth investigating. In the distance I saw a discarded tire and swam toward it. A moray eel thrust its head out menacingly, defending its absurd castle.

All eyes and jaws, a nearby lizard fish (below) awaited its



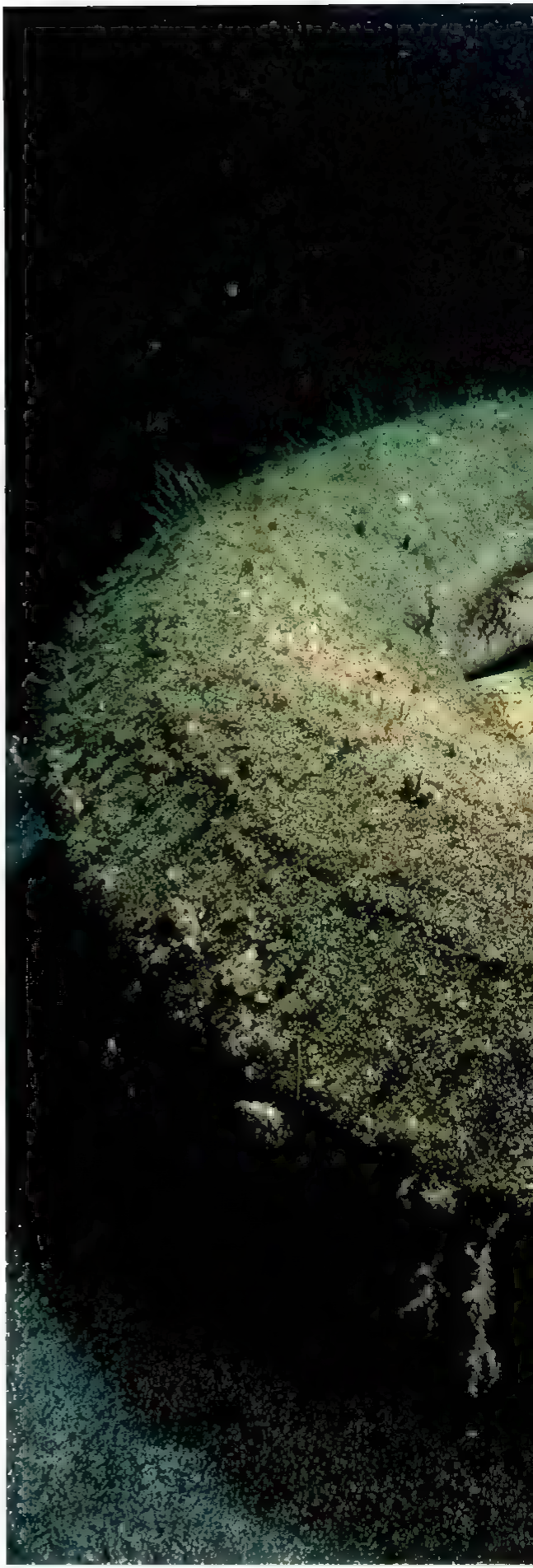
ULAE SCHULTZ



CALLIURICHTHYS JAPONICUS

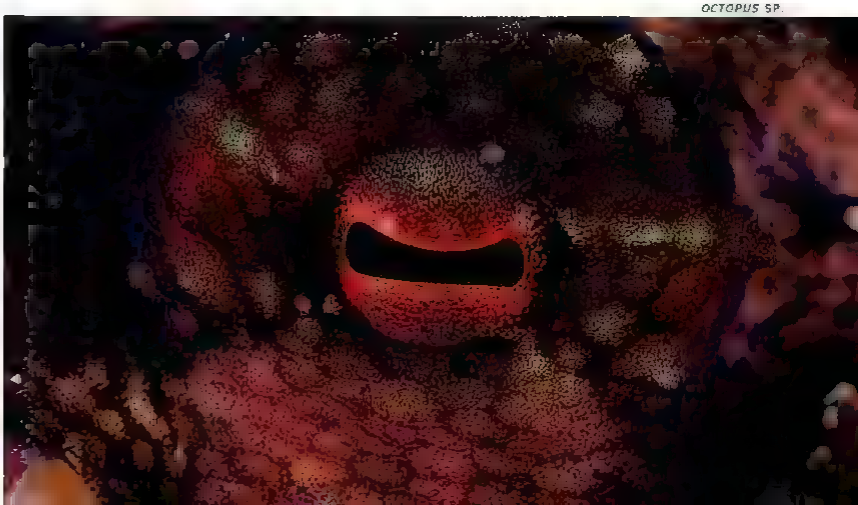
prey like a concealed weapon, sand bearded around its head.

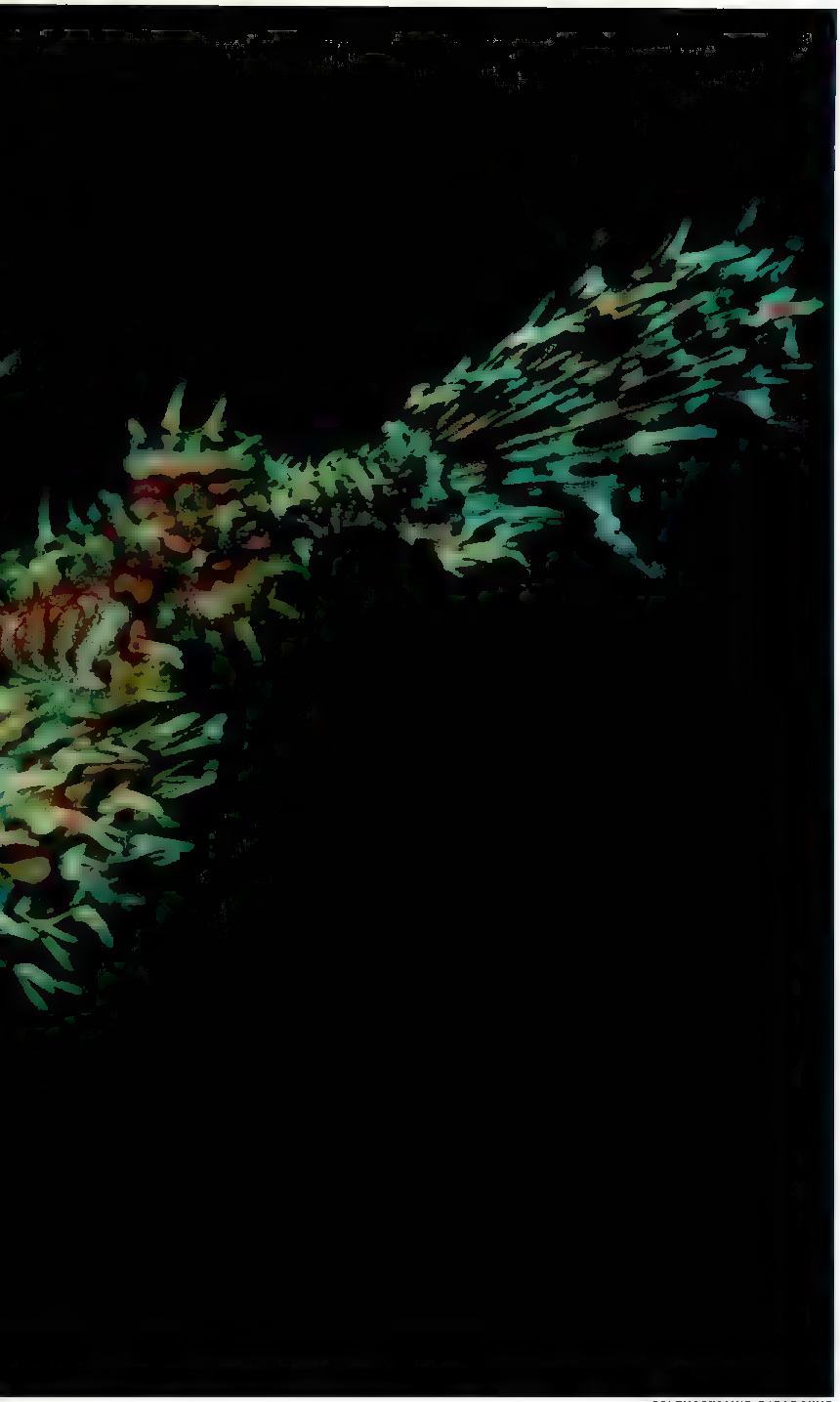
In the gray flannel world of the volcanic sand, the dragonet (above) must at times rise above its camouflage and do some serious advertising. The black spot on its dorsal fin is its trademark and may help it attract a mate or defend its territory. As I approached, the dragonet levitated like a Hovercraft. Then it sped away across the bottom and vanished in the gloom.



GYMNOTHORAX KIDAKO

OCTOPUS SP.





SOLENOSTOMUS PARADOXUS

ONE OF OUR DIVERS, photographer Yusuke Yoshino, pantomimed that he had found something wonderful and motioned for us to follow.

He led us to the upper edge of the sand field, where the bottom turns rocky on the upward slope toward the shallows. We crouched in a semicircle in front of him and waited.

He pointed at empty water. We shrugged. He pointed again. Again we saw nothing.

Then suddenly, in the water at his fingertips, two tiny ghost pipefish appeared, camouflaged so perfectly against the coral-encrusted rocks that they literally materialized before our eyes. It was a magical sight.

Close relatives of the sea horse, these creatures have hard exoskeletons and use their pipe-like mouths to pick out crustaceans from the seabed. But unlike the sea horse, whose male carries the eggs in an abdominal pouch, it is the large ghost pipefish female, foreground, that broods the young, sheltering them in the enlarged pelvic fins below her body.

Most impressive, though, is the pipefish's talent as a mimic. They don't just change color—they actually grow their spiky filaments, or absorb them, to match their surroundings. I have found pipefish wearing crusty red and black to blend perfectly with gorgonian coral. Others were sleek and smooth, dressed in green to look precisely like pieces of sea grass. Cancer researchers propose to study pipefish to see how this shrinking mechanism works, how its body can reabsorb unnecessary cells.

The pair we found in Suruga Bay were distinctly Japanese. They were tan and nubbly and looked as if they had been dipped in tempura batter. Immediately I made a chopsticks motion to my friend Koji, who understood and burst into a laugh, filling his mask with water. We called them tempura fish from that moment on. I turned back to the fish, and they were gone.

As I searched for them, I saw the eye of a small octopus (left) peeping through the sand. It was an eye as alien as the sea. Surrounding it were thousands of pigment cells, cells that change color as they react to light, to metabolic changes within the creature, or to the world around it. As the octopus waits to pounce on its next meal, its skin takes on the color of the sand. And its extraordinary pupil closes to a slit, refining its vision in the glaring, monotone world of the sand fields.

WE STAIRSTEPPED up the slopes of Suruga Bay toward the shallow water. At 15 feet, in the third hour of our dive, I found the squid.

I watched them hunting. Fifteen inches long, they would hang like little zeppelins, their silvery spotlight eyes catching every movement in the rocks below them. Then they would tilt downward, tentacles first, and begin to move imperceptibly toward their prey—fish, poor oblivious fish, trundling from one rock to the next. And then the pale squid, hovering like

SEPIOTEUTHIS LESSONIANA

angels of death, would strike, falling forward to envelop the victim with grasping tentacles.

They themselves are hunted with the same resolute passion. Above, I knew, in the late afternoon shadows, squid boats were preparing to mimic their prey. They would ride on the surface with spotlights ready, waiting for dark to come.

And in the world below, the squid too would wait, translucent creatures metallically reflecting light, composed mostly of water, blending into the shallow green curtain of the sea, hunting, waiting, watching.

BETWEEN THE ROCKS I found a hermit crab with vermilion claws wearing a shell decorated with the plume of a hydroid (below right). The effect was that of a comic-opera palace guard from a mythical European duchy. The crab's intentions, however, were serious, and it had carefully cultivated the roof of its home, adding an anemone to one side of the shell. Hermit crabs use their claws like tiny garden tools, picking and manipulating, coaxing marine life onto their shells. Thus the crab is camouflaged by the anemone and hydroid. They, on the other hand, are granted mobility.

While I was watching the hermit crab, I felt someone watching me. I looked up. A Japanese fisherman was above me in a small boat, peering through the surface of the sea with a "lookbox," a wooden scope with a plate of glass on the bottom. This lookbox fisherman, it seemed to me, was performing a last desperate fishing act, something that could completely harvest the shallows of this sea.

The schools of commercial fish in Suruga's shallow water have all but disappeared, and the fisherman was going after life between the boulders. This interstitial life, a megaversion of the life between the sand grains, is rich and varied and composed of crustaceans, fish, encrusting sea life, and grazing mollusks. But it too is disappearing from the waters of Japan.

Lookbox fishermen are armed with spears and long-handled implements that look like giant dental probes. I watched the fisherman's movements, silhouetted against a cloudy sky. Suddenly his probe came down with a little net attached and chased and caught a crab right next to me, which I had not even seen. Then a spear came down out of the watery sky and slammed into a fish, which somehow, magically, the lookbox fisherman had spotted.

To say that Suruga Bay is overfished would be a vast understatement. Large boats and rich markets have pushed fishermen deeper into the bay, and the development of nylon rope and net has allowed them to work more efficiently than ever. The haul from Suruga's deep trough, once rich and seemingly endless, now shrinks year by year. Even the giant crabs living a thousand feet beneath the surface are threatened.

Further damage is done by the millions of people living around the bay, who pollute it with both human and industrial waste.

Until now Suruga Bay has been saved by its enormous depths. It is a great storehouse of ocean water. The deep bay breathes life into the shallows, and the Kuroshio stirs new waters into its soul.

DARDANUS CRASSIMANUS

LONG AFTER my decompression meter told me it was safe to come up, I lingered in the shallows while my diving partners returned to the boat to shed their exhaustion and hunger. In the stillness I wanted Suruga Bay to myself.

I drifted into a seascape of ultimate simplicity—algae-covered boulders rising to join a mirror surface bordered by a softly breaking wave. Beyond, the rocks continued up into a world textured with moss and trees and soil.

I was at the edge of an ocean,

yet the late afternoon light and the stones and the surface, as elemental as they were, were like no other underwater vision. The seabed was empty, devoid of movement, more like a lake than an ocean. But between the boulders were hidden corridors of life waiting for the water to warm and fill the sea with spring spawn.

And behind me was a deep brooding bay, an extraordinary place of demons and dreams, guarded by a sacred mountain that in the coming darkness would change from an outline to a presence to a memory. □

The Cajuns: Still

With a style as spicy as boudin, a popular sausage, the Cajuns

Loving Life

are savoring their day in the sun.

By GRIFFIN SMITH, JR.

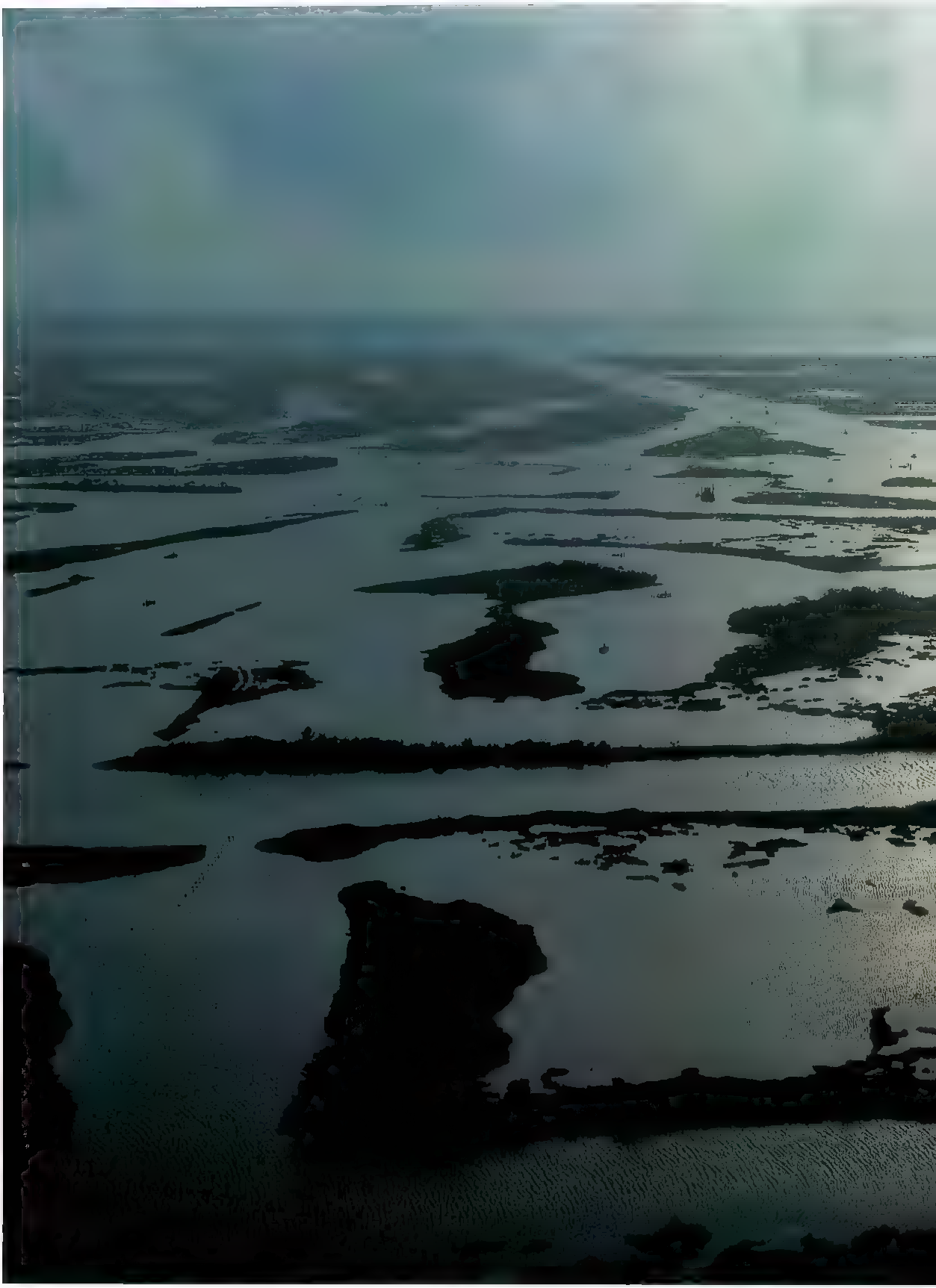
Photographs by
WILLIAM ALBERT ALLARD

HE WAS A BEARDED, stocky, hearty Cajun papa, treating three generations of his family to a pizza after the Krewe of Hyacinthians parade on Sunday afternoon in Houma, Louisiana. They were planning a party for Mardi Gras, just two days away. And while I couldn't catch every French-accented word, one admonition came through firm and clear.

"I don' wanna run out of beer," he said, "an' I don' wanna run out of crawfish."

With a chuckle I realized that after six weeks in south Louisiana, I'd found him at last. Here was the Cajun as the world imagines him to be: the easygoing, hard-drinking, seafood-loving denizen of the bayous, brimming with joie de vivre and always ready for a good time. And what was he eating? Pepperoni.

Along the course of those six weeks I'd had a lot of my expectations about Cajun country turned upside down. I'd met Cajun lawyers, bankers, professors, and captains of industry; I'd been welcomed into the homes of crawfish farmers and cattlemen, rice planters and musicians. Except for an occasional French-language sign, the legendary Evangeline country looked pretty much like the rest of the Gulf coast south. There were no fiddlers in the streets, no pirogues on the bayous. It took me a while to be persuaded that it was more than just a tourist come-on, that a proud Cajun subculture does indeed still thrive in the eddies of the American mainstream. Pepperoni yesterday, crawfish tomorrow: The genial Cajuns may be the country's prime



The world where earth and sea mingle has sustained generations of Cajuns with waterfowl, seafood, and pelts. Now this customary hunting and fishing ground is fast eroding. Navigation canals big enough for a barge and access canals to oil rigs,

such as these that slice the marshes of Timbalier Bay, bring saltwater ever farther inland along Louisiana's Gulf coast. Levees built to control the Mississippi River and its tributaries prevent the flooding that once renewed wetlands with silt.

"When I started painting 22 years ago, there was no such thing as Cajun art," says George Rodrigue. Collected on both sides of the Atlantic, his work recaptures the vitality of now faded folkways. In "Aioli Dinner" his grandfather meets friends for a meal that features the French garlic mayonnaise of the title.

example of an ethnic group that celebrates its own distinctiveness while remaining comfortably a part of 20th-century America.

CAJUNS ARE the descendants of 17th-century French colonists who settled along the shores of Canada's Bay of Fundy in a region they called Acadie. Expelled by the British in a series of deportations beginning in 1755, more than 2,500 Acadians eventually found refuge in Louisiana. As the years passed, their neighbors softened the edges of the French "Acadien" into " 'Cadien" and finally "Cajun." Many neighbors, including those of German and Spanish descent, were gradually absorbed by intermarriage into the Cajun milieu.

Today's Cajun country is a roughly triangular section of south Louisiana reaching from the outskirts of New Orleans to the Sabine River. It laps over the Texas line for a few miles past Port Arthur—"Cajun Lapland," as Louisianans sometimes say to needle their Lone Star relatives. Despite popular belief, New Orleans is not Cajun country. Nor is Baton Rouge. Nor is a great deal else that seems French in Louisiana, since a goodly number of French Creoles—a term that was originally used to describe people born of European parents in the New World—settled in the territory both before and after Cajuns arrived.

In 1971 the Louisiana Legislature designated 22 of the state's 64 civil parishes as Acadiana, remarking on the "strong French Acadian cultural aspects of said region." Mostly rural, and with a population that is by no means entirely Cajun, Acadiana centers around two unofficial capitals, Lafayette in the west and Houma in the east. Despite the dogged misconception that most Cajuns live in swamps, Acadiana actually divides into four geographic areas: the bayou country, consisting of fertile levee lands slowly built up by natural processes along the Mississippi River and lesser waterways; the coastal marshes, rich with oil and gas deposits but eroding now at an alarming rate; the inland swamps like the great soggy wilderness of the Atchafalaya Basin, virtually uninhabited; and the prairies of southwest Louisiana, an agricultural breadbasket of rice, cattle, and soybeans.

In one of those unexpected twists that keep life interesting, something about the Cajuns captured people's imagination a decade or more ago. Paul Prudhomme, a celebrated chef from Opelousas, was in part responsible. In 1980 he created an instant classic called blackened redfish and spread the gospel of Louisiana cooking from New York to San Francisco. Cajun cuisine, with its exotic ingredients and its reputation for high-octane seasoning, spawned legions of imitators.

The energetic fiddle-and-accordion songs like "Jolie Blonde" and "The Lake Arthur Stomp" set toes a-tapping far beyond the prairies of Acadiana. Cajun musicians found enthusiastic new audiences. Songwriter D. L. Menard, in real life a chairmaker in the tiny town of Erath, traveled to 42 states and 21 countries, from Thailand to Egypt, playing his

GRIFFIN SMITH, JR., a writer and lawyer in Little Rock, Arkansas, last wrote "Small-Town America" in the February 1989 NATIONAL GEOGRAPHIC. Photographer WILLIAM ALBERT ALLARD is a frequent contributor to the magazine.

1755–1757 In 1755 the first Acadians were deported south to British colonies. Turned away by Virginia, ships carrying 1,500 exiles sailed for Britain.

1758–1762 A second wave of deportation swept several hundred Acadians to France in 1758. By 1763 some 10,000 Acadians had been displaced—two-thirds of the original population.

1763–1785 After the French and Indian War ended in 1763, some refugees in the British colonies made their way north to French territory. Others moved to South America, the West Indies, the Falkland Islands, and Louisiana. In 1785 about 1,600 refugees left France for Louisiana.

Long journey to a new home

EARLY in the 17th century the Cajuns' pioneer ancestors founded a French colony called Acadie in what is now the Canadian province of Nova Scotia. While the Acadians prospered on the fertile farmland, France and Britain vied for control of the region. Britain won sovereignty in 1713; four decades later, at the start of the French and Indian War, security-conscious officials deported many Acadians.

Scattered along Atlantic and Caribbean shores (above), some refugees found a final home in south Louisiana. As their settlements spread across bayous and prairies (left), neighbors shortened the French "Acadien" to " 'Cadien" then "Cajun." Today 22 parishes, or counties, with a Cajun flavor make up a triangular region known as Acadiana.

guitar and singing his modern-day Cajun hit "The Back Door." For the 1988 Reagan-Gorbachev summit conference in Moscow, chef John Folse was invited to bring Cajun cooking to Mother Russia. He set up a temporary restaurant that required 16 tons of imported food, and artist George Rodrigue's hauntingly evocative paintings of turn-of-the-century Cajun life went on display there.

By the end of the decade you could walk down Main Street in Canada's Moncton, New Brunswick, and have a choice of Cajun jambalaya or spicy shrimp at not one but two restaurants. You could hear a French Cajun band play the old Louisiana standards in Paris and kick up your heels at the monthly Cajun dance in London's Cecil Sharp House. Or you could just stay home and wash down your Amazin' Cajun potato chips (from Dallas) with Original Cajun Flavored Beer (from Milwaukee).

ALL THIS COMMOTION has been fun. But Cajun purists like Barry Jean Ancelet fret that it may have gotten out of hand, giving the world an exaggerated caricature of the people he holds in affectionate regard. "There's good news and bad news" were the first words I heard from this

Every Saturday morning Marc Savoy, center, presides over a jam session at his music store outside Eunice. "I try to feature musicians who kept the torch burning when Cajun wasn't a nice word." At the Liberty Theater in town, folklorist Barry Jean Ancelet, with son Emile, prepares to host a weekly Cajun radio show.

lanky, droopy-mustached folklorist at the University of Southwestern Louisiana, who probably knows more about today's Cajuns than anyone else. "The good news," he deadpanned, "is that Cajun is hot. The bad news is that Cajun is hot."

Like most Cajuns, Ancelet winces at implications that Acadiana is full of fire-eating swamp dwellers who communicate in archaic French and have not yet joined the modern world. "It's ludicrous," he says. "In the movies Cajuns have replaced hillbillies as a people among whom heroes can get into exotic trouble." Businessmen trying to restore the area's oil-depressed economy worry that the tales of Cajun carousing will prompt prospective industries to dismiss south Louisiana.

For the rest of us, the only bad news may be that Cajun chic has left the best part of an amazing tale untold. That tale is the story not only of who the Cajuns are but also of who they were—and how they got here. Today's zesty south Louisianans are just one chapter in a nearly four-century saga of heartbreak, struggle, and perseverance against all odds. Many Cajuns know the story, as do their modern-day kin in Canada, New England, and France, because each of them has in some way lived it.

Doing his part to get the crop to consumers' kitchens, eight-year-old Hank Menard levels freshly harvested rice in a truck ready to take it to the mill. If seasoning is the soul of Cajun cooking, then rice is its body, adding substance as it soaks up the

pungent sauces. In September the Menards flood some of the fields and through the winter trap the crawfish that feed on the rice stubble. Cajuns say that these crustaceans, which are sometimes called mudbugs, taste far better than shrimp.

"It's a place where people just let go and have a good time," says a dance hall customer. Every town worth a two-step has one. There's Snook's in Ville Platte, Lakeview Club in Eunice, Fontenot's (now Richard's) in Basile. Fred's in Mamou

Set aside for a moment what you remember of *Evangeline,* Henry Wadsworth Longfellow's sentimental account of an Acadian maiden's separation from her fiancé, Gabriel, during the exile of 1755, because Longfellow's characters and many of his important details are now known to be mere fiction.

Early in the 17th century, settlers from western France came to what is now Nova Scotia's Annapolis Basin, a fertile land of orchards sheltered from winter winds by mountains to the north. They spread into rich land in the Minas Basin and along the Isthmus of Chignecto. Fishermen and farmers, they always hewed close to shore, constructing elaborate dikes to claim new cropland from the Bay of Fundy's 50-foot tides.

Their new homeland of Acadie lay squarely athwart the rivalry between France and England for mastery of North America. The Acadians declared neutrality, but the English, who had won control over their lands in 1713, demanded loyalty. When, in June 1755, the English overran France's Fort Beauséjour and captured some 300 Acadian conscripts inside, the fate of Acadie was sealed.

The English claimed treachery. Within months Acadians of the Minas Basin were being boarded onto British ships bound for the American colonies, their lands and homes in flames. Others either capitulated or fled into the forests. For years the roundup continued. Of an estimated 15,000 Acadians, 10,000 were captured, deported, or detained before the war between France and England ended in 1763.

Those who came to the American colonies faced wartime hostility and grew quickly destitute. Virginia's allotment of 1,500 Acadians was actually refused entry and shipped to England as war prisoners. At least seven hundred Acadians drowned when their overloaded ships sank in a storm on the way to Europe. The odyssey went on for years. In one chronicler's words, "the wretched exiles cropped up like driftwood along the littoral of the Atlantic Ocean and the Caribbean Sea." They made their way to France, Quebec, the French West Indies, Saint Pierre and Miquelon, French Guiana, and the Falkland Islands. By 1765 a few hundred had settled in Louisiana.

More than 2,500 impoverished Acadians congregated in French maritime ports, living

is famous for its Saturday morning crowds (above). By 9:15 a.m., when Don Thibodeaux and his Playboys strike up the music and the live radio broadcast begins, the drinkers and dancers are shoulder to shoulder.

on a dole from the French crown. For most, Louisiana was what destiny had in store. A plan was devised to reunite them with their kinsmen. Spain had gained control of Louisiana in 1762, and the king needed good Catholic settlers to bolster his dominion against English-speaking neighbors. He supported the plan, and from May to October of 1785, seven ships set sail from France, bringing their cargo of about 1,600 Acadians to Louisiana.

It has been called the largest single transatlantic migration up to that time, the end of a 30-year exile. Today, in hundreds of Cajun homes whose families are descended from those long-buffeted souls, someone can unfold a dusty, fan-shaped family tree and tell you not only the names of their ancestors but also the name of the very ship they took so long ago.

INSTINCTIVELY TRYING TO REBUILD their former life, the Acadians retreated into isolation along the bayous and in the open prairies west of the Atchafalaya Basin. In the passionless language of social scientists, many of them "resisted acculturation" well into the 20th century. "Before the Civil War," historian Michael Foret told me, "Cajuns were not as poor as people think. But the war caused a depression in the South that lasted until the 1940s." And on the social ladder Cajuns were near the bottom rung. Many led a subsistence existence, and many still remember it: Paul Prudhomme, sitting in the test kitchen of his renowned New Orleans restaurant, described how his own family "had bartered butter and eggs for other things." When Louisiana began to require school attendance in 1916, most Cajuns were illiterate. Their indifference to education lingered: "If you went to college," said Weldon Granger, a successful attorney who now lives in Houston, "people thought you were lazy." As late as the 1930s observers commented on Cajuns' "rude shacks" and their "chronic aversion to wearing shoes."

By 1950 three major things had changed all that: the oil and gas demand, which brought jobs; new roads, which ended rural isolation; and World War II, which thrust thousands of Cajun youths into the outside world.

When Weldon Granger invited me to attend his family's Christmas reunion in Erath, I was

Work hard, play hard, is the rule in Cajun country. At Mardi Gras in Mamou costumed revelers step lively to coax donations of gumbo ingredients from the farmers they entertain. The evening's public dance winds up at midnight, the start of Lent.

In New Iberia cars assemble for the Louisiana Sugar Cane Festival parade, the last chance for fun before the harvest.

prepared for a good time. I found it, certainly, but I also found a microcosm of many Cajuns' long upward climb from lower class to success.

When Weldon's father, Willis, joined the Navy in 1943, he spoke not a word of English; 20 years later he had 11 children, nine of whom went to college, several to graduate school.

For years Willis Granger and his boys were sharecroppers on nearby lands of the Thibodeauxs and Broussards, farming with a mule. His wife, Edith, born an Hebert, cooked and washed without running water. In the off-season Willis eked out a living trapping nutria and muskrat. "When Dad got a job in the salt mines on Jefferson Island," Weldon recalled, "it was a real step up. We could live in town."

Today, basking in his children's achievements (all have done well, and three sons are internationally known physiologists), the 68-year-old Willis runs a horse farm squarely across the road from where he used to sharecrop. With a white fence and a modern home, it looks like a bit of Bluegrass Kentucky. Weldon bought the tiny four-room house in Erath and moved it to the farm, a memento of the family's past. Willis has a Rolls-Royce Silver Cloud now, a whim of his lawyer son ("He uses it to go buy groceries," Weldon grins). But he still prefers his pickup.

At Christmas a hundred or so Grangers and Heberts came together at Erath's American Legion Hall from as far away as Venezuela to eat boudin (sausage) and dance to a Cajun band. Grandmothers *en banc* watched the doings; the men discussed the merits of the latest deer hunt; the children all behaved; and (surprise!) a well-stuffed Cajun Santa arrived to lead the two-step at the head of a conga line.

At his plush law office, Weldon Granger tells me why a painting of a man and boy picking cotton hangs in the place of honor behind his desk. "That's my dad and me," he says. "I had an artist take an old black-and-white photo and make it into a portrait. When I get a little cocky, I look back at that. I'm very appreciative of all that's happened."

THAT BLEND of simplicity and success typifies many Cajuns today. I never met a Cajun who put on airs. Composer-saxophonist Richard Landry, whose radiant "Mass for Pentecost Sunday" was commissioned for the opening of the Menil Collection, a sophisticated museum in Houston, wrote the work in his family's high-ceilinged old house in Cecilia, not far from where he once picked cotton for a dollar a day and played the saxophone in Otis Redding's band. Baseball pitcher Ron Guidry, one of the best the game has seen, was hanging a cypress cabinet in the kitchen of his new party barn on a 75-acre rural tract near Lafayette when I caught up with him. "It's a place for dances," he said—and for his bass boat. "This whole area is close, tight knit," the ex-Yankee told me, explaining why in retirement he came home to Cajun country. "I can walk ten square miles around here and know everybody."

With all the attention given to the Cajuns'

"There must have been 300 boats tied up for two miles on each side of the bayou," remembers Herman Broussard, one of the shrimpers who took shelter in Delcambre as a storm approached last October.

The state's most valuable seafood, shrimp powers the economy of many coastal towns. "When you have a good season, you know about

it because things move along real good. When the season's bad, everybody feels it," says seafood handler Ron Collins. At his Leeville dock, workers hustle shrimp off boats and into refrigerated trucks (left).

In master chef Paul Prudhomme's New Orleans restaurant, cooks transform fresh shrimp and other staples of Cajun home cooking into haute cuisine (right).

"My people were watermen who lived between the swamp and the salt marsh. Called it the trembling prairie," says champion decoy carver Tan Brunet, at left, outside his Galliano gallery. His son Jett, at his side, has already surpassed him. Both sell decorative decoys to collectors for thousands of dollars apiece.

Frenchness, it's easy to forget that they are Southerners too. Ron Guidry's love of hunting and fishing, typically southern, is mirrored all across Cajun country. "Everyone's got hunting camps," says Terry Perrin, who grew up almost within sight of Avery Island, the home of Tabasco hot sauce.

There is a special Cajun twist to this southern image. Perrin, a semiretired cook, explains, "Cooking is a man's thing. To cook your first gumbo while your friends are playing *bourrée*, a Cajun card game, well—it's sort of a rite of passage." As we talk, he sprinkles Tabasco on his popcorn between sips of beer.

MUSIC is the single most distinctive element in today's Cajun cultural revival. Originally for at-home listening, it soon became an accompaniment for dancing. The vocals, usually in French, are nasal and shrill enough to be heard over the sound of dancing feet; to an outsider they are an acquired taste. But the music itself—fiddle, triangle, accordion, guitar, and the more modern drums—is irresistibly infectious. There is nothing of the woeful history of Acadie in these cheerful melodies.

Cajun music had nearly died by the 1940s, absorbed by country music and "western swing," when a half-blind accordionist named Iry Lejeune made the old sounds fashionable again. A god in the Cajun pantheon, Lejeune, who died young, would be amazed at today's proliferation of restaurant-dance halls like Mulate's in Breaux Bridge, where Cajun bands play for hours every day. The shoes on the dance floor tell the story: cowboy boots, Adidas, deck shoes, slippers, dress shoes, sandals. In south Louisiana Cajun music crosses all divides of age and class.

At the Savoy Music Center near Eunice each Saturday morning Marc Savoy, master of the accordion, hosts a jam session. When I came in, the heavens were ringing with the sound of nine fiddles, four accordions, three triangles, a piano, and an upright bass. Stacks of boudin and six-packs of beer (the official "admission charge" for first-time onlookers) lay all about.

"My idea is, let's make a party, let's make a barn dance," says Savoy. In an era when some Cajun musicians are edging into rock, he firmly upholds the classic sound. "I don't want to play all this nouveau music. The earliest style, the purest style, that's the sound I've always tried to capture and pay tribute to."

IN MOST RESPECTS the main features of today's Louisiana Cajun culture hardly go back at all to old Acadie; furthermore Cajun life differs sharply from that led by their now distant cousins in Canada. Some 300,000 people proudly calling themselves Acadian reside in Canada's Maritime Provinces, mostly along the eastern shore of New Brunswick. (Another 25,000, a special breed of American Acadians, live across the St. John River in Maine's Madawaska region.) I went there expecting to find the other half of a seamless Cajun-Acadian world, separated from Louisiana's 500,000 Cajuns in distance but not in spirit. But what I found suggested that 200 years in Louisiana made the Cajuns there a separate people, bound to their northern kin more by sentiment than by substance.

Consider what sets today's Cajuns apart.

Their food, with its cayenne pepper, roux, and mingled aromatic flavors of onion, celery, and bell pepper, owes more to the Indians, the Spanish, and the slave cooks of the antebellum South than to the salted, oily foods of old Acadie. Rice is a Cajun staple, and well-loved ingredients like crawfish and alligator play a part in Louisiana as nowhere else. Only in the one-pot cooking style do the Cajuns share a culinary inheritance with the Acadians—but a gumbo or a jambalaya is a far different experience than the Acadian chicken-and-dumpling stew called *fricot*. Today's favorite Acadian dishes are *poutine* (a doughball containing salt pork) and rappie pie (a casserole of grated potatoes with the starch pressed out). Both are bland enough to put a Cajun palate fast asleep.

Classic Cajun music owes its heart and soul to the fiddle and to the diatonic accordion, something old Acadie never saw. Introduced to Acadiana by the Germans about 1850, it reshaped the old Cajun fiddle dance tunes, eliminating those that could not fit its limited range. For the most part, only waltzes and two-steps survived. Today's distinctive Cajun sound has few real counterparts in Canada.

The status of the French language is a fighting matter in New Brunswick, which in 1969 became officially bilingual. In Louisiana a smattering of French lingers, but the generation now in its 40s is the last to have grown up speaking it at home. With some exceptions—such as the French-language news program read by a Cajun accordionist every night on Lafayette's community TV channel—French is no more than a grace note in Cajun life, although efforts have begun to preserve it.

The Cajuns, one Louisianan told me, "have a sense of wrong without an attitude of militance." In New Brunswick the bold, single-starred Acadian flag flies proudly in front of homes and buildings, at times higher than the Canadian flag; in Louisiana an attractive flag of Acadiana was designed some years ago, but it has not become the same sort of political symbol. In a perfect illustration of Cajun moderation, a Lafayette lawyer named Warren Perrin recently petitioned the Queen of England to bring an official end to the Acadian exile by admitting that it was a violation of English and international law. "I *wanted to do this*," he told me, "so when my children ask why their ancestors came here, I don't have to say they were 'criminals.' It's never too late to correct a wrong."

The deepest difference between today's Cajuns and Acadians may be one of temperament. When the Cajuns celebrate who they are, they mean who they have become; when the Acadians celebrate who they are, they mean who they have been. One honors change, the other endurance. When I asked Acadians what qualities distinguished them from their English-speaking neighbors, they always mentioned the closeness of their family life, just as Cajuns did, but unlike Cajuns they never mentioned joie de vivre.

Joie de vivre: It may be the richest nugget of wisdom at the core of Cajun being—keeping in mind Cajun author Trent Angers's observation that joie de vivre is "not a state of euphoria that can be induced by the consumption of alcohol," but rather "a way of looking at things. . . . a condition of the mind and of the heart."

A millionaire before 40, industrialist Dailey J. Berard credits his success to Cajun ingenuity. "I grew up in a big old swamp and spoke only French," he recalls. World-traveled as a contractor for the oil industry, he has returned to New Iberia roots. "Once this place gets in your blood, you can never get it out."

Despite all the differences, the personal ties that bind Acadians and Cajuns are deep and warm. I think of the two Don Heberts, one in Port Arthur and the other in Madawaska, who met at a family reunion and have exchanged friends and friendship by the busload since. And I think of Carl Brasseaux, a young Cajun historian, who told me of the uncanny sense he had of "being among my own people" when he went to New Brunswick. "The rhythms of speech, the way they related to their children, so many things were so much the same."

How much, I thought, depended on the roulette wheel of exile more than 200 years ago: on who went where, and what they then became. Late one September afternoon at the Festivals Acadiens in Lafayette, after a stroll through food stalls where vendors sold crawfish tamales and alligator sausage po'boy sandwiches and chicken jambalaya, I listened while a popular band called Beausoleil brought the crowd to a joyous frenzy with its swirling Cajun tunes. Sunlight backlit the Spanish moss in ghostly gold. The dust from dancers' feet and smoke from family barbecue grills rose around me. If the original Acadians came back just now, I wondered, would they recognize the Cajuns? Would they say, in them we overcame our loss? Or would they say, part of our punishment was for our descendants to become a different people we no longer understand?

With a twinge of regret I supposed it was the latter: The exiled Acadians might find a part of themselves in Canada or Maine, but Cajuns, bless their souls, would simply baffle them. So be it. Cajun culture is happy with itself.

FOR ALL the good-natured qualities of Cajun life, south Louisiana still has its share of troubles. Erosion of the state's coastal wetlands, which account for 40 percent of the production of U. S. fisheries, is occurring at the rate of one acre every 15 minutes. The process has been going on for centuries, as the Mississippi River has changed its course every few hundred years, whipping across Louisiana like a garden hose, but levees and canals have worsened the loss of land to the point where much of Terrebonne Parish—it means "good land"—could be gone in 50 years.

Cajun shrimpers along Bayou Lafourche

With faith a cornerstone of Cajun society, heartfelt prayers and a bishop's blessing begin the sugarcane harvest. Married in a church ceremony, Bernard Rees wears the cash customarily pinned to newlyweds by dancing partners at their reception.

bemoan rising costs and new environmental laws that require TEDS, or turtle excluder devices, funnel-like attachments that, in theory, deflect endangered sea turtles while shrimpers trawl. "The shrimp are supposed to go in," says Linwood Cheramie, a little wiry man whose ready smile fades when the subject is TEDS. "But if anything gets caught in the opening, like paper, you lose all your shrimp." Cheramie has worked as a shrimper for 53 of his 67 years. "I didn't expect to make a fortune," he says in the kitchen of his modest home in Golden Meadow, as his wife serves us coffee and crusty French bread from Dufrene's Bakery a block away, bread fresh enough to please a Parisian. "I'm doing it because I love to do it.

"You know what's pretty?" he interrupts himself, unfolding a sheaf of snapshots of his boat decorated with hundreds of colored flags for the blessing of the fleet each August. He invites me aboard his well-kept pride and joy, and he starts the motor. It purrs like Willis Granger's Rolls-Royce.

"It looks like the shrimp industry is a thing of the past," Cheramie muses. "Your expense is $15,000 a year to catch $25,000 worth of shrimp, if you work hard. If a young man had to go out and buy a boat like this, he couldn't make a living. But," he pauses, and that irrepressible smile breaks out again, "it's still fun to go out just with 'frans' to go fishin'. What's 30 gallons of diesel fuel for frans?"

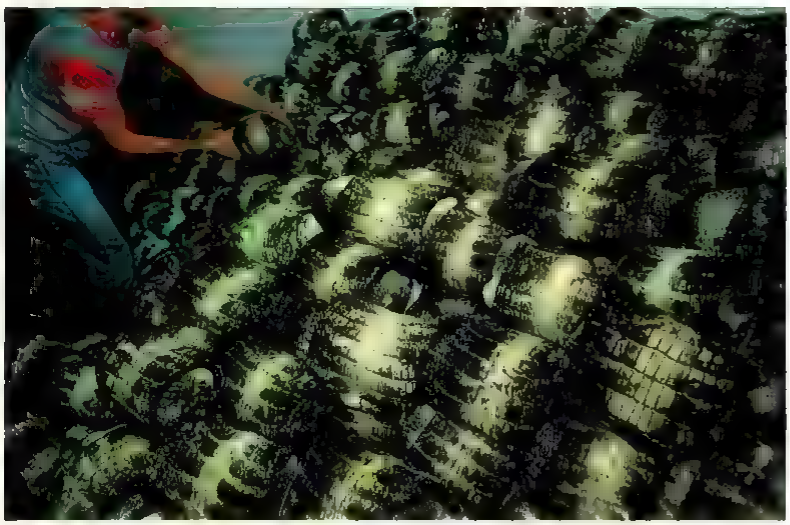
Broad and open, lined with hundreds of boats, the long reach of Bayou Lafourche at Galliano and Golden Meadow will surprise anyone who thinks that "on the bayou" means a moss-hung, dark, tree-shaded, slow-moving way of life. By day a busy waterway, it glitters at night with thousands of mercury vapor lights. There is a bustle to the place that belies its isolation.

The few remaining swamp Cajuns, by contrast, lead a Faulknerian existence that is fast disappearing. In the Atchafalaya Basin more of the deep swamp is silting up each passing year. Almost all the residents have moved to more comfortable quarters outside the levees; a 90-horsepower Yamaha can zip them into their fishing grounds and back out in an hour or two, so the traditional houseboats that people like Annie Blanchard remember from childhood are long gone—or are turned into casual weekend retreats.

Annie and her husband, Roy, live in what

could pass for a typical suburban home down a gravel road on the levee south of Catahoula, but their hearts—and their livelihood—are still in the swamp. Competition from crawfish farms, though, has cut their income badly. "Used to be, you'd make a living so easy it was free," Roy says as we sit in their living room, the television playing wordlessly beside us. "But they started these crawfish farms, and that makes it hard." The worldwide crawfish craze has not made Roy and Annie any richer.

"If I had to leave this place and go farther," Roy says, "I'd be like a sick dog. I can still hear the wood ducks and the little green frogs."



Rolled up for storage, skins from Wayne Sagrera's alligator farm in Abbeville (left) may fetch as much as $35 a foot. Meat to be sold for human consumption in this country and abroad shares the cooler with the bodies of two nuisance alligators removed from the wild. Cajun hunters who brought home gator for the stewpot were ahead of their time. "It's very healthy meat, high protein, low fat," says Sagrera.

At home in the saddle, horsemen round up cows and calves on a foggy October morning. The herd belongs to Johnny Broussard, who rents 4,000 acres of pasture in Vermilion Parish, Louisiana's top cattle-producing area. In keeping with Cajun

tradition, Broussard and his neighbors work together on the fall roundup. "One thing about down here, you can always call one of your neighbors," says another rancher. "He'll drop whatever he's doing and come give you a hand."

Annie nods in agreement. "That's the music of the swamp."

PERHAPS THE BIGGEST BLOW to Cajun country was the oil bust of the 1980s, which shattered the economy of south Louisiana and left places like Lafayette reeling. "It was a grotesque specter," says developer Dwight Andrus. "You were lucky to catch your breath on the way down. I will never forget it. Fear. Fear. Fear." So massive was the exodus, U-Haul shipped loads of automobile trailers into Lafayette on railroad flatcars. Hardest hurt was what another Cajun called "our false middle class that oil produced." Jobs came so easily during the boom, he said, "you could make good dollars and not even finish high school." When the bust came, "people had to leave the area, and their families, to find work. It was the final exile, or maybe I should say the latest exile."

Later I went to see Dave Petitjean, a popular Cajun humorist. He and Justin Wilson, the teller of Cajun tales, have surely made more people laugh than any other Louisianans. One of Petitjean's favorite bits of Cajun wisdom lodged in my memory. "Love life," he said, "and life will love you back."

So I ask him: After all the adversity the Cajuns have known—working in salt mines, suffering in the oil bust, picking cotton for a dollar a day, getting expelled from Acadie and sailing the seas in search of home, watching their bayous silt up and their coastline wash into the Gulf—how can anyone say that life has loved them back?

He smiles the smile of someone who just may have been asked all this before.

A brash label and a bayou gator tattooed on the upper arm of crawfisherman Chad Boudreaux proclaim him one hundred percent proud of his heritage. From good-old-boy boatmen in the Atchafalaya Basin (left) to business executives in the city, Cajuns everywhere celebrate their culture with high spirits.

"We have a saying: '*Lâche pas la patate*—Don't let go of the potato,' " he says. "It means 'Hang in there.' What Cajuns have is our mystique, our outlook on life. Cajuns don't let things destroy them. Not even our odyssey could destroy us."

A few days later the great Cajun accordionist Marc Savoy echoed those words as we sat on his back porch. "What's Cajun?" he mused. "It's the spirit, the attitude of whatever happens, it's for the best. It's the outlook about everything. How do you see the things around you . . . how do you work . . . how do you play . . . how do you sin? It's not about speaking French. It's what you got right here under your chest. That's what's Cajun."

But will it endure in mainstream America, where the Cajuns so clearly have decided to be? Michael Foret, the historian, thought so. "I think there'll always be something about the Cajuns that will be at least marginally different from people in Ohio or Utah or Michigan. And it works both ways: Maybe the 'Americans' are catching some of our joie de vivre. I think we've had some permanent influence on American ways of thinking."

From what I had seen, each of them was right. Life has loved the Cajuns back, not least because they willed it so. And perhaps decades from now, when the French language is barely a memory in south Louisiana, when the lilting Cajun music is kept in a cupboard for the delight of connoisseurs, when the gumbo and the crawfish and the jambalaya have given way to fast foods we cannot now even imagine, then there will still remain, like a lingering smile of grace from the bayous and the prairies, that disposition of the mind and heart. □

Is Our World Warming?

Under the SUN

For more than four billion years the sun and the earth itself have been the driving forces in our planet's changing climate. Now we puny humans—in all our billions—may have become the decisive force for change in the decades ahead.

By SAMUEL W. MATTHEWS
SENIOR ASSISTANT EDITOR

Photographs by JAMES A. SUGAR
BLACK STAR

THE SUN SETS BEHIND COLORADO'S FRONT RANGE. FIVE-INCH TELESCOPE IMAGE BY JOSEPH SUTORIK, SPACE ENVIRONMENT SERVICES CENTER/ NOAA, BOULDER, COLORADO.

SMOKESTACKS IN SOUTHERN CALIFORNIA, LARRY LEE, WEST LIGHT (ABOVE); RUSH HOUR ON THE BAY BRIDGE IN OAKLAND

The power of sunlight captured millions of years ago by plants and animals and buried in huge deposits is now being burned as coal, petroleum, and natural gas. Such burning in power stations, automobiles, and homes releases carbon dioxide (CO_2) to the air. Once airborne, CO_2 absorbs heat, warming the atmosphere in the so-called greenhouse effect.

Their faces to the setting sun, mirror-winged solar panels convert even the last rays of the day directly into electricity.

JAMES A. SUGAR AND KEVIN SCHUMACHER

These southern California collectors add a clean and inexhaustible energy source to the state's power grid.

THE ROAD up earth's most massive mountain—Mauna Loa on the Big Island of Hawaii—is a narrow, twisting strip of tar, laid by prison labor through raw, jagged lava fields. You can drive it—with great caution and constant awe—to a small cluster of white and blue huts standing more than two miles high in the clear, cool Pacific sky.

Here for 32 years the level of carbon dioxide in the earth's atmosphere has been recorded daily at the Mauna Loa Observatory by Charles David Keeling of the Scripps Institution of Oceanography and by scientists from the National Oceanic and Atmospheric Administration (NOAA). And for 32 years the level has risen, in a wavy curve of spring-fall variations (opposite), from 315 parts per million (ppm) in 1958 to more than 355 in mid-1990.

That steadily climbing CO_2 level (air locked in glacial ice a century ago held only about 280 ppm—25 percent less) is an incontrovertible measure of what man and his machines have done to the atmosphere of the earth in scarcely one lifetime. Because of it, say many scientists who study the climate, our planet is bound to become warmer—has already warmed—as more and more energy from the sun is caught and held in the thin blanket of air around us.

"As Pogo put it, the enemy is us," said Elmer Robinson, director of Mauna Loa Observatory, while we drove together up the desolate slope of the volcano. "By burning more and more fossil fuel—gasoline, natural gas, coal, peat—even ordinary firewood, we are putting into the air more of the gases that act much like a globe of glass around the planet. That's what's called the greenhouse effect.

"Up here we measure not only CO_2," he went on, as he led me through a laboratory jammed with humming recorders and glowing computer terminals. "We also read methane, chlorofluorocarbons, nitrous oxide, and ozone, all of which add to the warming. We see and measure dust of various sizes in the troposphere, the weather layer of the atmosphere."

Such data, recorded by NOAA here and at American Samoa in mid-Pacific, at Point Barrow in Alaska, and at the South Pole, form the hard evidence on which climatologists base widely varying and controversial visions of the future. Average temperature worldwide, by careful calculations, has gone up about half a degree Celsius—one degree Fahrenheit—since the late 1800s.

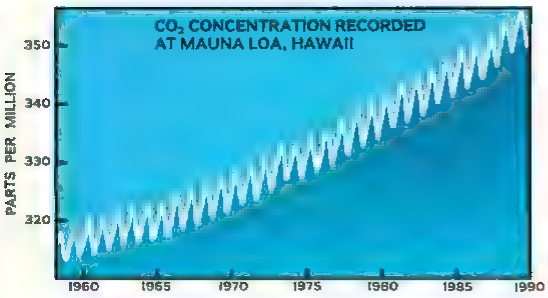
In this century, the decade of the 1980s saw the six warmest years in weather records. Yet there are some researchers and statisticians who argue this apparent warming of the planet may be only a temporary blip, that natural warming periods have occurred before, without man's intervention, and that there is as yet no sure evidence of long-term change.

All this was in my mind under the blaze of sunlight that beautiful winter day atop Mauna Loa. Through a small occulting telescope maintained there by the National Center for Atmospheric Research at Boulder, Colorado, I stared at the darkened face of the sun, ringed by its glowing, gauzy corona.

From that blazing disk high in the Hawaiian sky comes the

An unusual sight in San Francisco, smog hides the city only four or five days a year. Far more ominous: the invisible but relentless rise of carbon dioxide in the atmosphere. Scientists on Hawaii's Mauna Loa, two miles above the Pacific Ocean, have recorded a steady increase in the global concentration of CO_2 since 1958 (right). The zigzag pattern reflects the seasonal growth and dieback of plants, which soak up prodigious amounts of CO_2 during spring and summer.

A century ago CO_2 measured 280 parts per million, according



to analysis of air trapped in ice sheets. Scientists say this evidence shows the effects of human activities such as burning fossil fuels. Most believe the rising CO_2 level will lead to higher global temperatures and significant climate change.

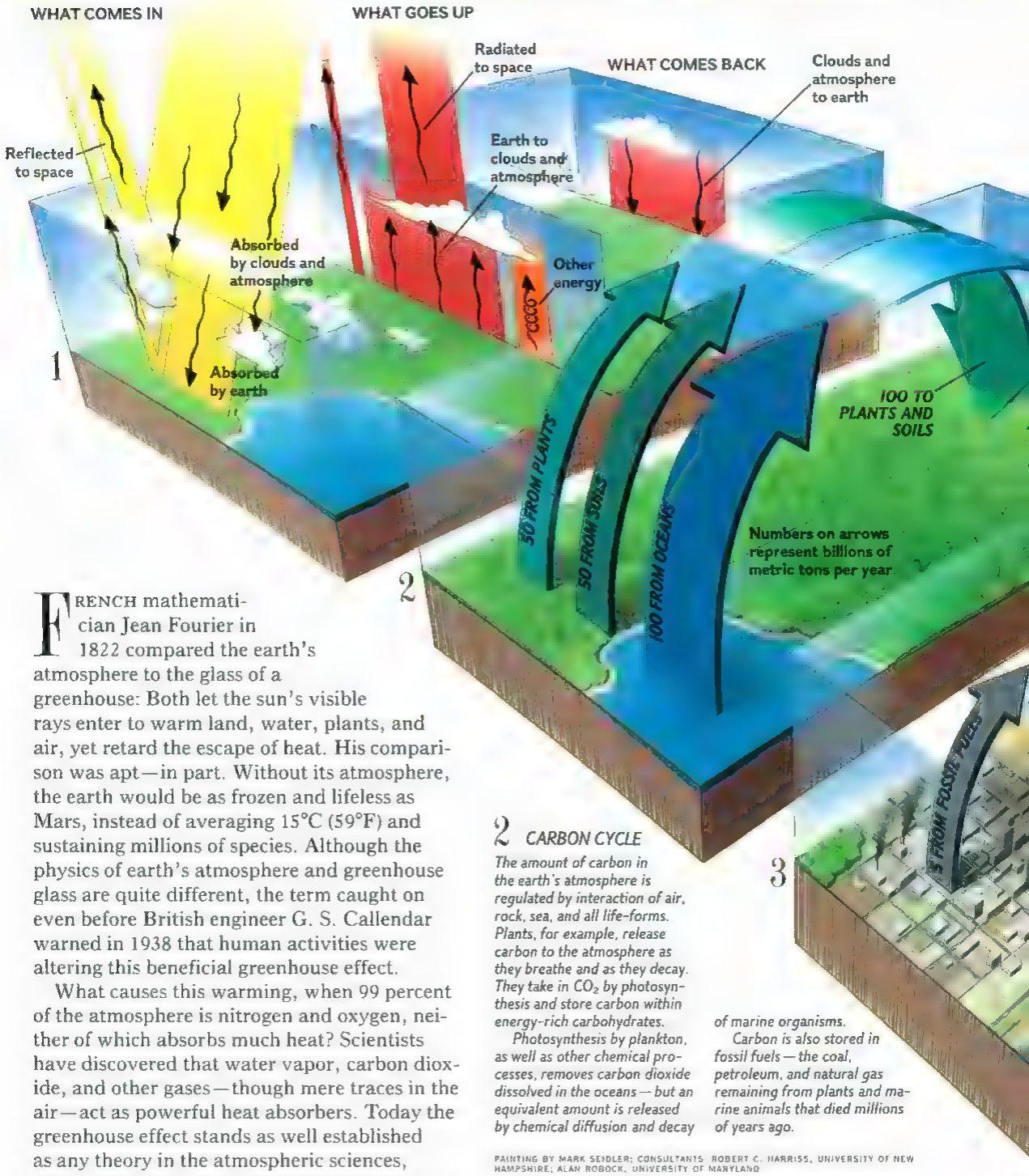
endless power that drives and rules all life on earth: its plant growth and the food chains of all its creatures; the winds, rains, and churning weather of the planet; the ocean currents, forests, prairies, and deserts.

Our home star in the heavens burns steadily, almost without variation. It is the "almost," coupled with what man's activities are doing to the atmosphere, that this story is about. It is becoming more and more apparent that the effects of the sun upon our planet are changing. Our one and only home may be in harm's way, and we can scarcely sense just what is happening—or know what to do about it.

That burning energy of our sun works the miracle on earth called photosynthesis. Powered by sunlight, plants green with chlorophyll combine carbon dioxide from the air with water from soil or sea into energy-rich carbohydrates, releasing into the atmosphere the oxygen we need to breathe.

It is the same process by which primitive bacteria of ocean shallows, more than two billion years ago, first produced enough oxygen to permit other life on earth to develop. And it is the

Earth's thermostat: the greenhouse effect



1 NATURAL GREENHOUSE

As radiation from the sun (yellow) enters earth's atmosphere, a portion of it is reflected back into space or absorbed directly by the atmosphere. The 50 percent or so that reaches the ground is converted into infrared radiation, or heat (red). Clouds and greenhouse gases such as water vapor and CO_2 absorb most of the heat that the earth radiates back toward space. These gases then reradiate the heat. Over time, the outgoing radiation balances the incoming.

Other energy (orange) includes latent heat released by formation of clouds and convective heat carried by updrafts.

FRENCH mathematician Jean Fourier in 1822 compared the earth's atmosphere to the glass of a greenhouse: Both let the sun's visible rays enter to warm land, water, plants, and air, yet retard the escape of heat. His comparison was apt—in part. Without its atmosphere, the earth would be as frozen and lifeless as Mars, instead of averaging 15°C (59°F) and sustaining millions of species. Although the physics of earth's atmosphere and greenhouse glass are quite different, the term caught on even before British engineer G. S. Callendar warned in 1938 that human activities were altering this beneficial greenhouse effect.

What causes this warming, when 99 percent of the atmosphere is nitrogen and oxygen, neither of which absorbs much heat? Scientists have discovered that water vapor, carbon dioxide, and other gases—though mere traces in the air—act as powerful heat absorbers. Today the greenhouse effect stands as well established as any theory in the atmospheric sciences, anchored by countless measurements from satellites, weather balloons, and ground stations.

2 CARBON CYCLE

The amount of carbon in the earth's atmosphere is regulated by interaction of air, rock, sea, and all life-forms. Plants, for example, release carbon to the atmosphere as they breathe and as they decay. They take in CO_2 by photosynthesis and store carbon within energy-rich carbohydrates.

Photosynthesis by plankton, as well as other chemical processes, removes carbon dioxide dissolved in the oceans—but an equivalent amount is released by chemical diffusion and decay of marine organisms.

Carbon is also stored in fossil fuels—the coal, petroleum, and natural gas remaining from plants and marine animals that died millions of years ago.

PAINTING BY MARK SEIDLER; CONSULTANTS ROBERT C. HARRISS, UNIVERSITY OF NEW HAMPSHIRE; ALAN ROBOCK, UNIVERSITY OF MARYLAND

ART AND DIAGRAMS FOR THIS ARTICLE
DESIGN: ALLEN CARROLL; RESEARCH: WENDY GORTESI, LISA R. RITTER, DAVID W. WOODDELL

same process—still imperfectly understood—that grows the corn of Iowa, the grass of your lawn, the rain forests of Brazil, the floating plankton that sustains life in the seas.

"Without carbon dioxide in the atmosphere, life as we know it would be impossible," Elmer Robinson had said on Mauna Loa. "We couldn't exist if it weren't for greenhouse warming."

About half of the radiant energy reaching earth from the sun, because of its short wavelengths, can pass through the atmosphere to the earth's surface. But the longer waves of heat that radiate back toward space are absorbed and reradiated by water vapor, carbon dioxide, other gases, and clouds, and the atmosphere warms.

"That's the greenhouse effect," Elmer had said. "Without it, earth would be frozen—at least 60 degrees Fahrenheit colder—and there would be no more life here than on Mars. But if it were to increase. . . . Well, some climatologists say we face temperatures three to nine degrees higher in the next century."

Back in the last glacial age, some 20,000 years ago, world temperature averaged about nine degrees colder than today. The carbon dioxide level was only 190 to 200 parts per million, ancient ice samples from Greenland and Antarctica show. As the ice melted back, the CO_2 level gradually rose to about 280 ppm by the beginning of the industrial age.

"By the middle of the coming century—in our children's lifetime," Elmer had said, "the level will reach 550 or even 600 at its current rate of rise."

The prospect of doubled CO_2—and even more rapid rise of other gases, such as methane, which together equal the warming effect of CO_2 in the atmosphere—is what has atmospheric scientists urgently refining their computer models of the climate.

World population also is predicted to double by the middle of the next century, from five billion people to ten. And as all nations become more developed and use more fuel to support those people, the release of carbon dioxide and other gases to the air is bound to keep increasing—despite the care taken or which fuels are burned.

With more warmth and more CO_2, some ask, would not more crops grow, in wider areas than today? Would we not benefit from a warmer world?

Perhaps, in some areas. The more CO_2 in the air, the more productive some plants become. But the biggest unknown is what changes would occur in the planet's weather patterns.

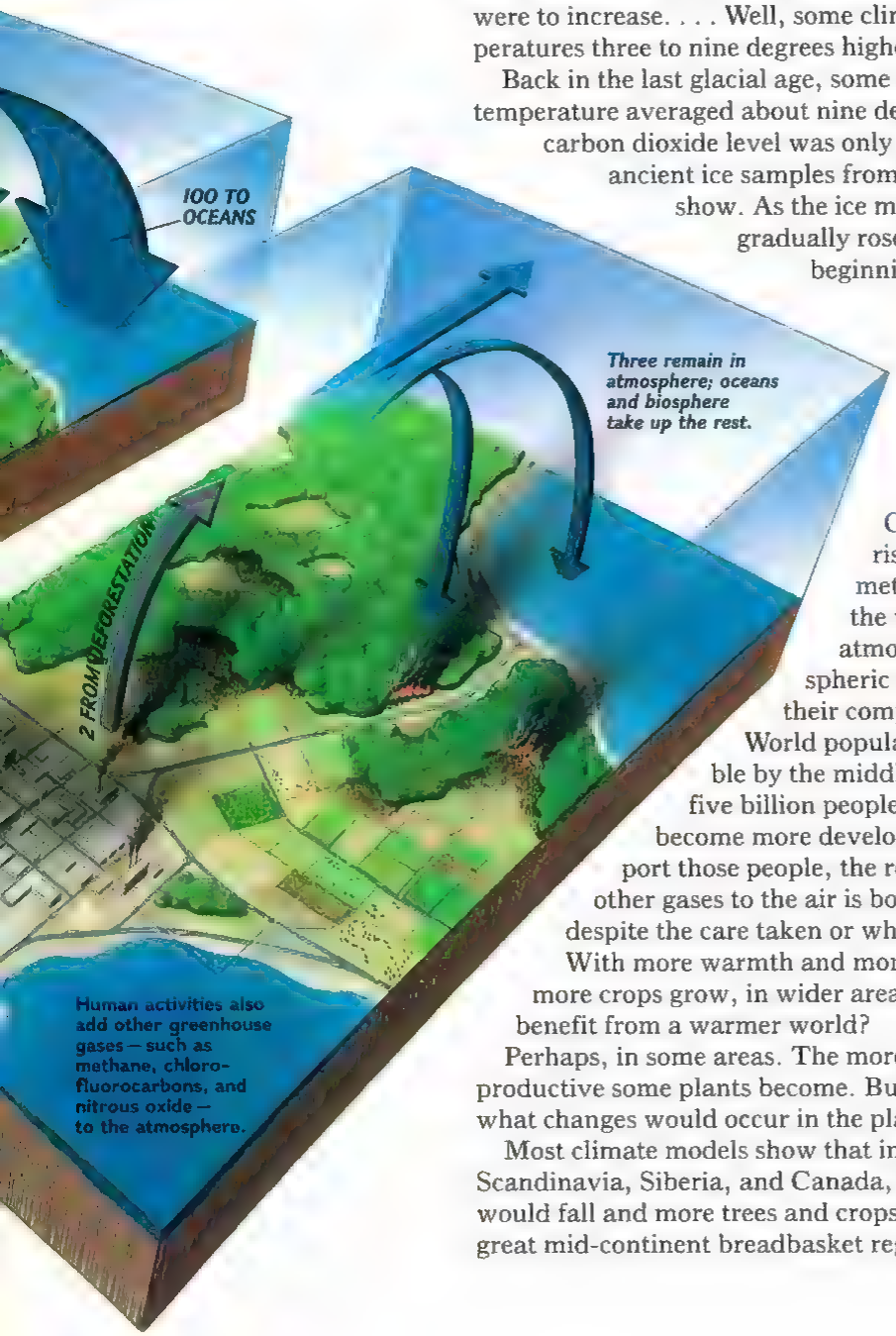
Most climate models show that in some regions—northern Scandinavia, Siberia, and Canada, for example—more rain would fall and more trees and crops grow. But in today's great mid-continent breadbasket regions, warming would lead

3 HUMAN INFLUENCES

Humans have disrupted the natural carbon cycle by burning fossil fuels for energy and by clearing forests to feed and house growing populations. Yearly about 50 million acres of forest are lost to logging, farming, and pasturage.

Industrial and agricultural emissions raise atmospheric carbon by about seven billion metric tons a year. Roughly half is absorbed by the oceans and by vegetation and soils.

Emission of greenhouse gases can be reduced, but no technology is available to remove them once they reach the atmosphere.


100 TO OCEANS
Three remain in atmosphere; oceans and biosphere take up the rest.
2 FROM DEFORESTATION
Human activities also add other greenhouse gases—such as methane, chlorofluorocarbons, and nitrous oxide—to the atmosphere.

On the road to understanding sources of methane, scientists from the National Center for Atmospheric Research in Boulder, Colorado, test what turned out to be an innocent suspect—fresh asphalt (above). Wide-ranging research suggests that leaks and venting from coal, oil, and natural gas production may be underestimated.

Cattle, a known source of methane, are increasing worldwide—faster than the human population. The same bacteria that enable a cow to turn grass into meat or milk cause it to expel methane, roughly 14 cubic feet a day.

to the drying of soil in summer. Destructive droughts, such as that of 1988 in North America, would strike more often, until the Great Plains and Ukraine turn semidesert. Storms such as hurricanes and tornadoes might become more violent. Forests would decline and change under the temperature rise, and wildlife would have to migrate—if it could—or perish. The permafrost under Arctic tundra would thaw, deep peatlands would decompose, and vast new amounts of carbon dioxide and methane could be released.

And just as inevitably, as ocean waters warm and expand and the ice on Greenland and Antarctica melts back, the seas would creep higher onto the edges of the continents. Large parts of such low countries as Bangladesh—already swept by ruinous floods and typhoons—would be submerged; cities like Miami, Venice, even New York, would cower behind dikes.

"If a rise of one to three feet, as the models have predicted, seems extreme," says environmental scientist Stephen Leatherman of the University of Maryland, "keep in mind that the oceans rose more than 300 feet after the last ice age—all in only a few thousand years."

If the ice cap on the island of Greenland were to melt completely, glaciologists estimate the oceans would rise another 20 feet. Sea level in the eastern United States has already risen a foot in this century alone, and it is predicted to go up at least another foot in the century ahead. With that one-foot rise, Leatherman says, the high-water line at Ocean City, Maryland, will move inland 100 to 200 feet; in Florida, 200 to 1,000 feet; in Louisiana, several miles.

Yet paradoxically, say other glaciologists, the huge ice domes on both Greenland and Antarctica may not be shrinking but growing. The paradox is that this too may be a sign of global warming. As the atmosphere warms, it holds more water vapor from evaporation of oceans and soil; hence more snow falls in the polar regions, hence more ice and possibly lower sea levels. But the warmer seas eventually will melt back the fringes of the polar ice, and the oceans will creep inexorably higher.

FORETELLING WHAT MAY HAPPEN to the world if it should warm by even one or two degrees is the toughest problem facing climatologists today. Even though there have been times in the dim geologic past when temperatures were warmer—with no ice at all on the polar regions—there are vast differences today. No one knows whether the "wild card" of human activity will disrupt or make more extreme the cycles ordained by nature.

To try to predict the effects of human intervention, scientists mathematically simulate the weather systems of the globe. Their equations, called general circulation models (GCMs), are so complex that only a few of today's supercomputers can solve them.

The equations relate such things as the balance of radiation to and from the planet, air circulation, evaporation and rainfall, ice cover, sea-surface temperature—then try to assess what might happen if the sun were to become brighter by a tiny amount or if the carbon dioxide in the atmosphere gradually doubles as expected. The computers then calculate and map the changes in

the weather of future days, weeks, seasons—or centuries.

One key to their accuracy lies in how finely they divide the planet's surface, the blanket of the atmosphere, and the seas. Most now divide the globe into blocks of at least five degrees of latitude and five of longitude: 300 nautical miles on a side, roughly the size and shape of Colorado. The best models then divide the atmosphere into as many as 20 layers and add in the oceans' currents and multiple layers. The computations are so formidable that a supercomputer might take a week to run a single change of input to determine its effect.

ON A HIGH SHELF of Colorado's Front Range, where deer roam in the open above the university town of Boulder, stand the sand-hued buildings of the National Center for Atmospheric Research (NCAR), one of the principal climate-modeling centers in the nation. The others are NASA's Goddard Institute for Space Studies (GISS) on upper Broadway in New York City and NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey.

The computer room at NCAR, its floor carpeted with bright red squares, is a futuristic assemblage of multicolored cabinets, computer terminals, and blinking panels of lights. The chief of the center, Bill Buzbee, showed me two red-and-black cylinders, each about five feet in diameter and five feet high, with segments seemingly cut out of them like huge wedges of cheese.

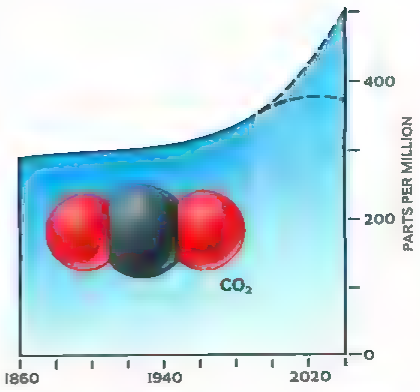
"Those are our Cray supercomputers," Bill said. "Not many exist in the world. If you'd like to buy one, it might cost you about 20 million bucks. And it would not be powerful enough for much of the modeling we're asked to do."

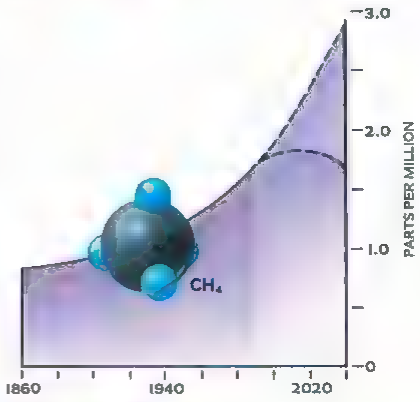
"If our global grid were reduced to two and a half degrees on a side and the number of vertical layers increased," I had heard Jerry Mahlman, director of GFDL, say, "it would multiply the demand on the computer 16-fold; at one degree square, which might be necessary to forecast weather and climate accurately for local regions on the globe, the order of complexity—and computer time—would go up at least 500 times."

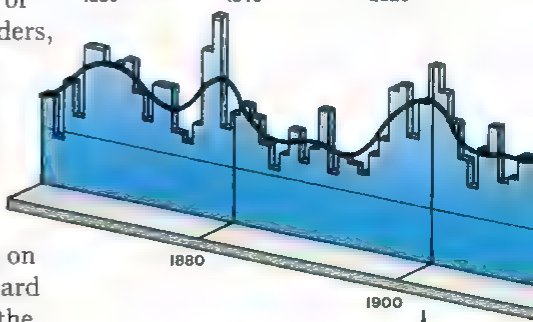
I began to appreciate what these machines do. They reduce inconceivably complicated systems of the atmosphere and oceans to logical, mathematical predictions of what might happen if man or nature changes the ways things are with the world.

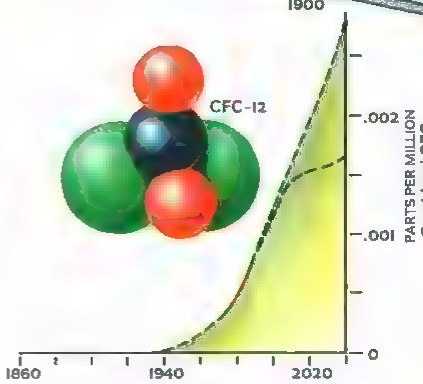
All the most advanced GCMs, fed a doubling of carbon dioxide, come up with similar results: The world will warm by the middle of the next century by two to five degrees Celsius—three to nine degrees Fahrenheit—with even greater warming in the subpolar latitudes. The differences between the models show up in regional effects (maps, pages 82-3): exactly where drying or more rainfall may occur, whether the Northern and Southern Hemispheres may react differently.

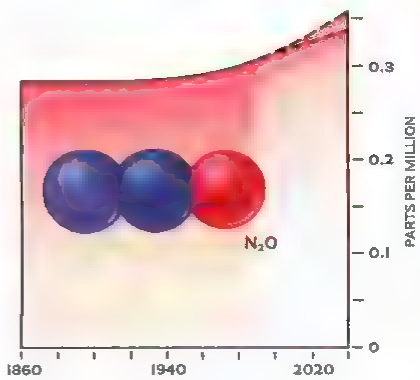
The modelers acknowledge they may be as much as a decade away from full confidence in their results. At GFDL they have been trying for 20 years to couple ocean circulation to the atmosphere. Syukuro Manabe, one of GFDL's most noted modelers (page 80), admits that in the early days "all sorts of crazy things happened [in the computer] . . . sea ice covered the tropical oceans, for example."









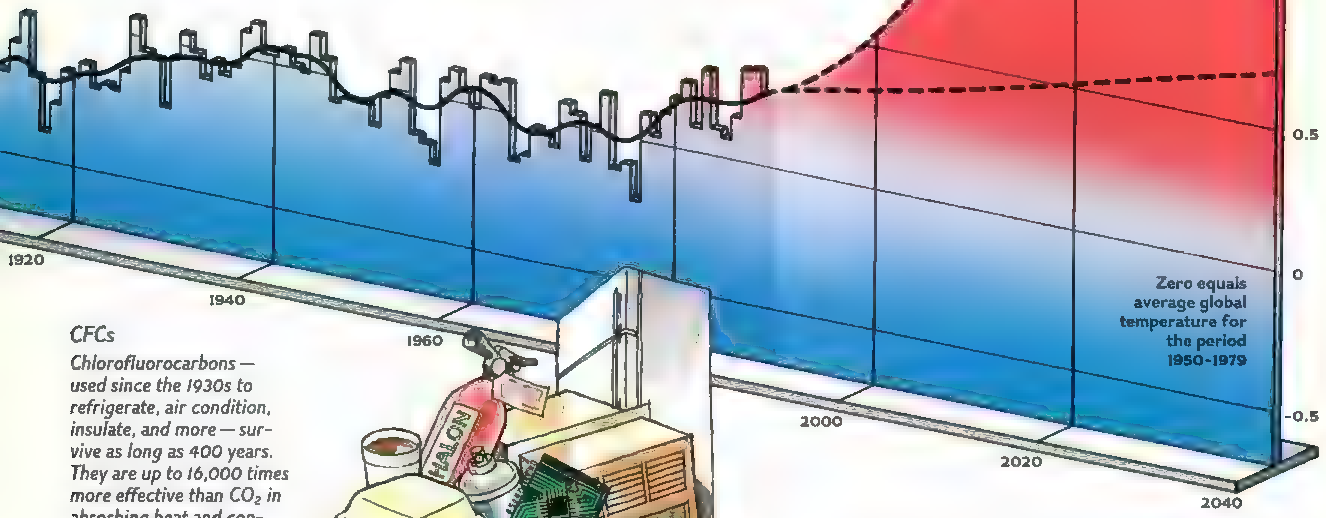


Fever chart of a warming planet

GLOBAL TEMPERATURE is like a mortgage rate: Over time a slight change can make a big difference. After about A.D. 1350 a drop of 0.5°C (1°F) starved out Norse settlements in Greenland and forced farmers in Europe to abandon fields. Since the mid-1800s, with increasing industrialization, average global temperature has risen by 0.5°C.

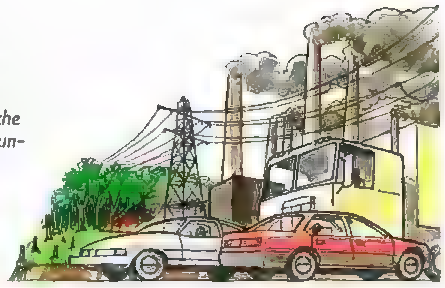
Some scientists link that recent rise directly to the heat-absorbing gases that humans have released to the atmosphere. Other scientists are less certain, stressing natural variability and changes in solar output. Few, however, doubt that the changing composition of the atmosphere will lead to some warming.

The graphs (left) project future accumulations of greenhouse gases along two lines—with business as usual and with aggressive actions to limit release. Projected temperature increases (above) range from 0.7°C to 3°C by 2040.



CARBON DIOXIDE

Rising with the smoke of burning fossil fuels and cleared forests, CO_2 lasts up to a hundred years in the atmosphere. The most abundant heat-absorbing gas after water vapor, it accounts for roughly half the man-made share of the global warming problem.

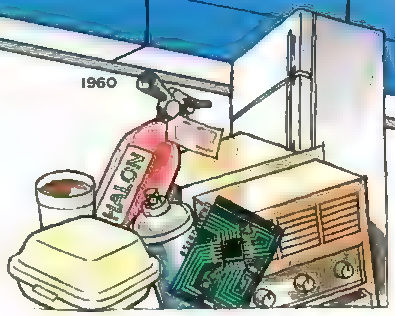


METHANE

Although methane lasts only ten years, molecule for molecule it absorbs 20 to 30 times more heat than CO_2. Most methane is generated by bacteria breaking down organic matter in the absence of oxygen, as in flooded rice fields, the guts of cattle, and landfills. It contributes 15 to 20 percent of man-made additions.

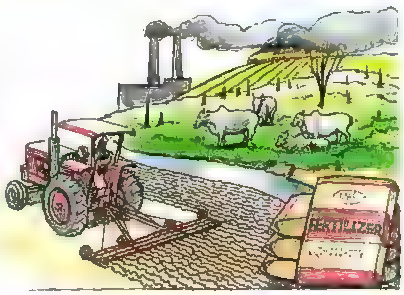
CFCs

Chlorofluorocarbons—used since the 1930s to refrigerate, air condition, insulate, and more—survive as long as 400 years. They are up to 16,000 times more effective than CO_2 in absorbing heat and contribute some 20 percent of man-made additions.



NITROUS OXIDE

N_2O, laughing gas, plays a somber role in the atmosphere, where it can last 180 years. Produced by microbes in soils, its increase comes from chemical fertilizers and slash-and-burn farming as well as by fossil-fuel emissions. N_2O is 200 times as heat absorbent as CO_2, adding about 5 percent to the man-made burden.



HISTORICAL TEMPERATURE GRAPH: UNIVERSITY OF EAST ANGLIA, U.K.

PAINTINGS BY NGS STAFF ARTISTS WILLIAM H. BOND AND CHRISTOPHER A. KLEIN (MOLECULES); GRAPHS BY DALE GLASGOW
ART CONSULTANTS: BARBARA BRAATZ, ICF INC.; ALAN ROBOCK
GAS GRAPH DATA: R. A. HOUGHTON AND G. M. WOODWELL, WOODS HOLE RESEARCH CENTER; ICF INC., FOR EPA; NASA/GISS; G. I. PEARMAN, COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH CORPORATION

ANOTHER NOTED climate modeler—and spokesman for potential trouble—is James Hansen, director of NASA's Goddard Institute (GISS) in New York City (facing page, bottom). During the scorching hot, dry summer of 1988 he captured international attention when he testified before a Senate subcommittee.

"The world is getting warmer," he said bluntly. "We can state with 99 percent confidence that current temperatures represent a real global warming trend, rather than a chance fluctuation. We will surely have more years like this—more droughts and many more days above a hundred degrees—in the 1990s."

He repeated these predictions in subsequent scientific meetings and climate symposiums—upsetting colleagues who felt he should hedge his concerns with more qualifications and maybes. But that is not Jim Hansen's way.

Some have heard and heeded what he and others have been saying. Senator Albert Gore, Jr., of Tennessee, one of the most outspoken politicians calling for action in the face of world warming, has said bluntly: "The greenhouse effect is the most important environmental problem we have ever faced. [It threatens] loss of forests, widespread drought and famine, loss of wild species . . . topsoil, stratospheric ozone. . . . Do we have the capacity, the will, to change habits of millennia in a generation?"

Stephen H. Schneider of NCAR (right), an intense, curly-haired prophet of the future, has been deeply involved in climate research for more than 20 years. He writes, speaks, and travels incessantly; he is one of the worried scientists to whom policymakers listen carefully.

"I agree with Jim Hansen and others that the world has gotten warmer over the past century—faster than ever since about 1975," he told me. "I'm not so quick to say it's entirely due to the greenhouse effect—though that's certainly there. Natural climate variations may be at work too, reinforcing—or at other times masking—the greenhouse forcing. In coming decades some years and some parts of the world may be cooler, but others will be much warmer than normal.

"The 1988 drought in North America, for example, has been linked by colleagues at NCAR with the El Niño phenomenon of the tropical Pacific Ocean. A shift in the jet stream, caused by massive ocean-atmosphere interactions in the Pacific, was the likely cause of that hot, extremely dry summer.

"But whatever the local and temporary weather changes, the world can't wait for proof of warming before trying to do something about it. We're engaged in a huge experiment, using our earth as the laboratory, and the experiment is irreversible. By the time we find the greenhouse warming *has* damaged earth's ability to feed its people, it will be too late to do much about it."

What would he have us do about it now? Try to slow the release of greenhouse gases—by more rigorous energy conservation and changes in fuel use (natural gas releases half as much CO_2 as coal); by reducing the burning of rain forests, which increases the level of CO_2 in the air; and by planting many more trees, wherever possible.

"Keep in mind, it's not only carbon dioxide that's at fault," Steve Schneider points out. "Methane, which is released from

Looking ahead, climatologists using advanced computer models to predict global warming trends have attracted wide attention—and occasional skepticism. Critics say that modeling is in its infancy and cannot even replicate details of our current climate. Modelers agree, and note that predictions necessarily fluctuate with each model refinement.

The modelers include Syukuro Manabe of NOAA's

decomposing tundra and marshes, rice fields, termites, and the guts of cattle, is increasing in the atmosphere faster than CO_2, at something like one percent a year. And molecule for molecule it has 20 to 30 times the greenhouse effect of CO_2. Nitrogen gases, from fertilizers as well as car exhausts and factory smokestacks, chlorofluorocarbons (CFCs) and other industrial products—all the other gases we're pouring into the air—are already doubling the warming potential of CO_2 alone.

"We can hope to reduce some of them, such as the CFCs that attack stratospheric ozone," he said. "But the others go with the industrial development of the world; all we can realistically hope is to slow their release, to gain time to cope with the results.

"If we can delay a 2°C increase of global temperature from 2025 to 2050, we will have more time to develop alternate energy sources: Nuclear—possibly fusion—is one option, despite its problems. But tapping the sun directly, by solar heat plants and converting sunlight directly into electricity, is both possible and coming down in cost."

I was to see his future in California, at the Rancho Seco nuclear plant outside Sacramento, flanked by 20 acres of solar panels slowly swinging with the sun across the sky; at a pioneering solar-cell factory near Los Angeles, where a breakthrough in "thin-film" technology was closing in on conventional electric power costs; and on a treeless mountain pass above Oakland, where a seemingly endless array of propellers taps the sun's energy from the winds sweeping in off the Pacific (pages 92-3).

COMPUTER FORECASTING of climate is uncertain for reasons other than the sheer complexity of the equations. There are variables and feedbacks that even the best of the models barely approach.

The oceans are the chief reservoir of heat, controlling weather over the entire globe. As currents such as the Gulf Stream carry the heat from the tropics to high latitudes, cold water from the polar regions sinks and flows toward the Equator, overturning the seas about every thousand years.

"The tropical oceans are the driving mechanism of the climate," says climatologist Eric J. Barron of Pennsylvania State University. "The oceans are the memory of the climate system," adds Kirk Bryan of GFDL at Princeton. Yet until recently even the most advanced mathematical models treated the oceans only as vast, shallow swamps.

Carbon dioxide is absorbed by seawater, some of it incorporated into the shells of tiny marine creatures that die and become carbonate sediments on the bottom. Scientists estimate that a significant part of the seven billion metric tons of carbon released into the air each year is taken up in the seas. Oddly, the colder the water, the more CO_2 it can hold. As the oceans warm under the effect of more CO_2 in the atmosphere, there is great uncertainty about how much of that new CO_2 will be absorbed. Is there a limit to how much carbon can be locked away? Have the oceans already reached their holding capacity?

World-famed geochemist Wallace S. Broecker of Columbia University's Lamont-Doherty Geological Observatory worries that rapid switches in ocean circulation might occur under

Geophysical Fluid Dynamics Lab (left), Stephen Schneider of the National Center for Atmospheric Research (left, below), and James Hansen (bottom) of NASA's Goddard Institute for Space Studies.

Might not the sun's 11-year sunspot cycle or irregularities in solar output directly affect earth's climate? It is an intriguing but unanswered question for astrophysicists like John Eddy (below), director of the Office for Interdisciplinary Earth Studies in Boulder.

relatively small changes in global climate. Ice and seafloor core samples show that there have been sudden climate changes in the past, he says, from warming conditions to marked glaciation and back in as little time as a century. It could happen again.

AS THE SEAS AND AIR WARM, more water evaporates into the atmosphere, creating more clouds and another great enigma to the mathematical modelers. Much is yet unknown about the net effects of clouds on global weather.

"Clouds are the window shades of the planet," says Steve Schneider of NCAR. "They may be even more important than the oceans or the greenhouse gases in regulating the heat received from the sun."

In daylight low thick clouds reflect sunlight back into space and have a cooling effect. At night they hold in heat radiated from the surface and thus warm the atmosphere. High thin clouds, such as cirrus, may act differently, also adding to the greenhouse effect. Storm clouds transport and release vast amounts of heat.

The incredibly complicated interactions of the atmosphere, land, and oceans lead many scientists to doubt that local and regional weather patterns can ever be accurately predicted for more than a few days into the future. Listening to atmospheric physicists discuss the new mathematical science called chaos is a form of mental mugging; they speak of random walks, strange attractors, and climatic ripples such as the "butterfly effect"—the notion put forward by MIT meteorologist Edward Lorenz that the flap of a butterfly's wings in Peru could lead to a tornado in Kansas. Yet these are today's frontiers of understanding.

The limit of that understanding leads Eric Barron of Penn State to quote Mark Twain's famous droll remark: "The researches of many commentators have already thrown much darkness on this subject, and it is probable that, if they continue, we shall soon know nothing at all about it."

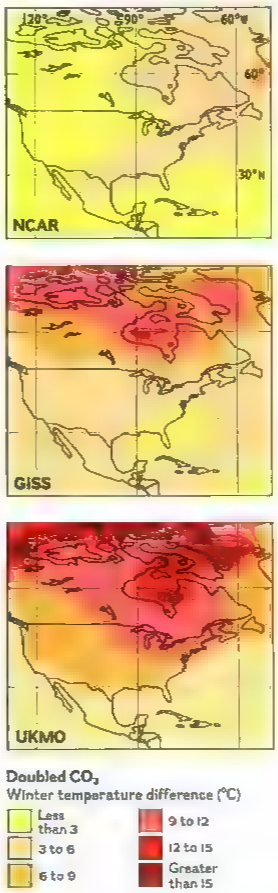
Feedbacks—the relationships between the natural forces that control climate—will be the crucial key, most modelers agree: clouds affecting surface temperatures; rainfall and droughts changing soil moisture, vegetation, and evaporation; snow and ice melting from ice caps and glaciers, changing the reflectivity of the planet and raising the level of the seas.

Forecast from a clouded crystal ball

INVOKING STORMS of numbers, scientists use computers to simulate how our planet might respond to an expected doubling of carbon dioxide. Their work, based on mathematical models originally designed for long-range weather forecasting, suggests that the earth will warm significantly in the coming century, bringing many changes in regional temperature and rainfall patterns.

What changes exactly? So far that's impossible to say. As complex as the models are—only a few of the world's supercomputers can run them—they remain rough representations of reality. Moreover, because the models use different methods, their regional predictions vary widely. Three of the climate models (left) differ markedly as to how North America will warm.

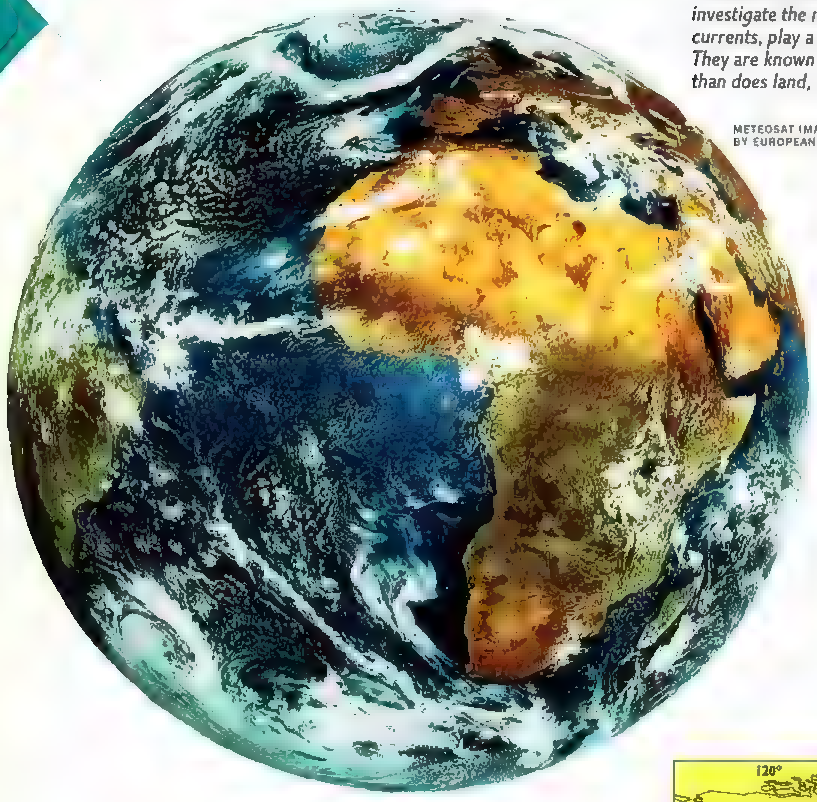
Current models do agree on the high probability of warming, and with it major—and unforeseeable—climatic changes. Because the models perform well in simulating seasonal variations and climate over thousands of years, most scientists take their overall predictions seriously.



NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (NCAR)
NASA/GODDARD INSTITUTE FOR SPACE STUDIES (GISS)
UNITED KINGDOM METEOROLOGICAL OFFICE (UKMO)

Complexity challenges climate modelers. Clouds both warm and cool the planet, and scientists continue to investigate the net effect. Oceans, with their deep currents, play a large—but poorly understood—role. They are known to warm and cool much more slowly than does land, in effect storing up change.

METEOSAT IMAGE PROVIDED BY EUROPEAN SPACE AGENCY

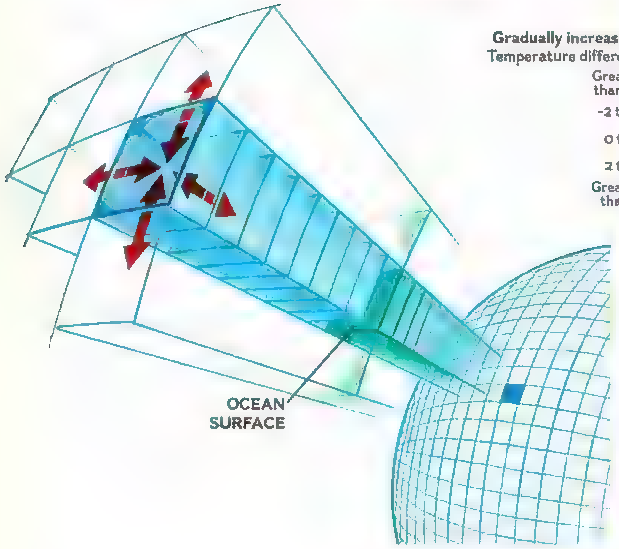


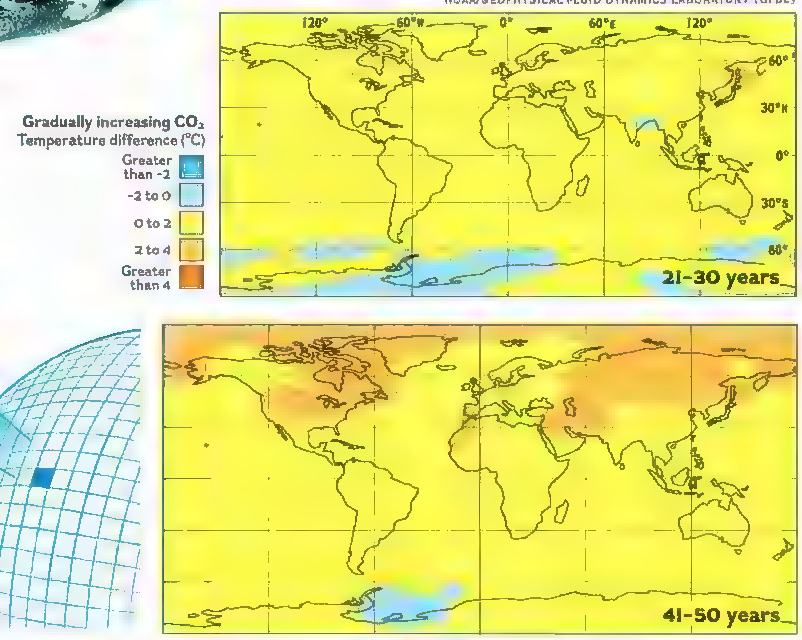
Rather than programming a computer simply to double CO_2 levels, recent models attempt to track change over time, more accurately depicting the gradual way heat-absorbing gases accumulate. Researchers at the Geophysical Fluid Dynamics Laboratory told their supercomputer to increase CO_2 by one percent a year from a starting date of 1958.

After 30 computer years (below) global surface temperature had risen by an average of 0.7°C. (Remember that these are computer simulations and do not give results identical to what actually happens in the real world.) After 50 simulated years, the temperature had risen by 1.4° C. And after 70 years, when CO_2 had doubled, it had risen by 2.1°C (3.8°F). The biggest surprise: The waters around Antarctica failed to warm as expected.

These models reveal new patterns, clues that scientists may soon be able to check against field data to see how their predictions hold up.

NOAA/GEOPHYSICAL FLUID DYNAMICS LABORATORY (GFDL)





To manage their data, modelers divide the earth's surface into boxes. Typically each box is about 300 nautical miles on a side and is sliced into layers of atmosphere and ocean. Based on average conditions within each layer, such as wind, temperature, sunlight, soil moisture, and relative humidity, the computer calculates how internal processes will affect the surrounding boxes. As the calculations are modified again and again, weather patterns emerge. Simulated seasons change just as real seasons do.

PAINTINGS ■ MARK SEIDLER
CONSULTANTS: KIRK BRYAN AND SYUKURO MANABE, GFDL; ALAN ROBOCK

Plate Carrée Projection

NGS CARTOGRAPHIC DIVISION

Earthmovers replaced tugboats on the Mississippi River in 1988, as drought brought record low water that grounded barges near Memphis (above). The drought slashed U. S. corn production 30 percent, boosting the volume of futures trading at the Chicago Board of Trade (right). Wichita farmer Larry Steckline and son Greg (left) lost $80,000 of wheat. Many scientists believe that while it didn't directly cause this devastation, global warming will make droughts and storms more frequent and severe.

More volcanic eruptions, throwing fine dust and gases high into the stratosphere, might operate against the greenhouse, cooling the earth temporarily. But the best computer models suggest that to bring on marked cooling, volcanic explosions far more violent than those of Mount St. Helens in 1980 or Krakatoa in 1883 would have to occur every five years for as long as a century. The resulting dirty air and acid rain would be worse for life on earth than global warming.

If a return to ice-age conditions rather than greenhouse warming sounds farfetched, it was thought a serious possibility as recently as the mid-1970s. The nine major interglacial periods of the past million years have each lasted scarcely 10,000 years before the cold returned—and it has now been longer than that since the last great continental ice sheets melted back. And even though global temperature has been rising since the start of the industrial age, from 1940 until 1970 it leveled and even declined slightly in the Northern Hemisphere.

J. Murray Mitchell, Jr., senior climate researcher of the U. S. Weather Bureau and later of NOAA's Environmental Data Service, was one of those who documented that downward drift. Now retired, he told me recently: "We thought natural forces, such as volcanic activity or perhaps variation in the sun's radiance, might be at work. But we still don't know whether it was a real change or just a quarter-century-long twitch in the climate cycle."

DOES THE SUN BLAZE absolutely uniformly, sending always the same amount of light, heat, and other radiation into space? Is its total radiance constant, as has long been assumed, or does the energy received by the earth vary, even minutely? The question is crucial in today's climate studies.

From astrophysical evidence the sun is thought to have been 25 to 30 percent dimmer when the earth was young—three and a half billion years ago. Pondering how life could have developed

under this "faint young sun," earth scientists postulate that a super-greenhouse effect must have been at work, with 100 to 1,000 times as much CO_2 in the atmosphere. Otherwise the surface of the planet would have been frozen solid, and photosynthesis impossible. Yet it indeed occurred, absorbing much of the carbon dioxide and producing the oxygen in the atmosphere necessary for the evolution of life.

In the time of modern science the sun's radiation has seemed absolutely steady. Astronomers have tried for more than a century to detect any change in the "solar constant." It was only in the past decade that they succeeded.

The answer lay in taking solar instruments above the unsteady window of earth's atmosphere, into the black clarity of space. That goal was reached in February 1980 with the launch of the Solar Maximum Mission (SMM) satellite, dubbed Solar Max. It went into space to read solar output just as the number of sunspots—the dark areas on the sun's face that signal changes in its magnetic activity—had reached a peak in their 11-year cycle.

By 1985 Solar Max showed a real, though very slight, decline in the sun's brightness. The drop was only about one-tenth of one percent, but to solar physicists such as Richard Willson of the Jet Propulsion Laboratory, a principal scientist of the project, it was startling. If there is an actual fluctuation of the sun's output of even that small amount, it might have a long-term, measurable effect on global weather.

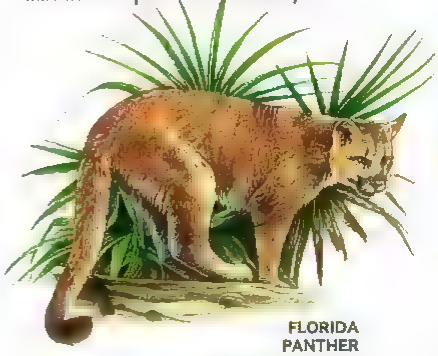
In 1986 the number of sunspots reached a minimum, as predicted. Shortly after, there began a rapid increase in sunspots—greater than in any previous solar cycle of this century. Scientists expected the upturn to continue until the next peak in 1990 or '91, but an unforeseen hazard put the Solar Max project in peril.

As the sun's activity increased, it warmed the outermost fringe of earth's atmosphere slightly, causing it to expand. The added drag began to slow the satellite, and it dropped in its orbit by a few kilometers. Instead of circling the planet at least until 1991, Solar Max began tumbling in August 1989, and by early December ended its life as a fireball of blazing metal in the sky.

TUNDRA AND BARREN LAND
CONTINUOUS PERMAFROST
Alaska (U. S.)
KIRTLAND'S WARBLER
CONSULTANT: DANIEL B. BOTKIN, UNIVERSITY OF CALIFORNIA
PAINTING BY H. DOUGLAS PRATT
OTHER PAINTINGS BY ROBERT HYNES

The Kirtland's warbler, which nests only in Michigan on the sandy soil favored by jack pines (map, right), could lose its entire habitat within 30 years.

Such rare or endangered species are the most vulnerable to rapid climate change. Yet many more species are at risk. Even now, before evidence of such change, innumerable species are lost each year.



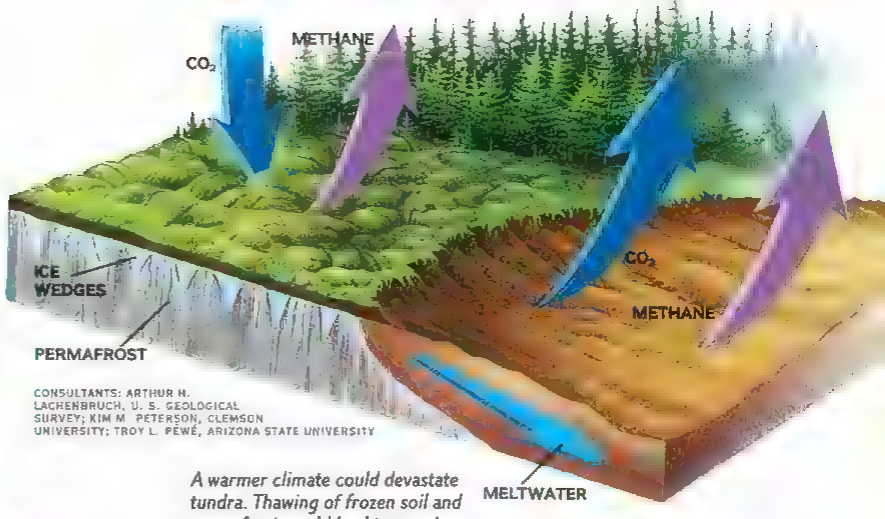
Water expands as it warms. Expansion of seawater and partial melting of glaciers could raise sea levels a foot or more by 2050, according to many scientists. That apparently slight change would inundate shorelines worldwide, send saltwater farther into estuaries and groundwater aquifers, destroy coastal wetlands, and increase frequency of storm damage. Numerous species would be threatened, including the Florida panther, whose habitat has already been reduced by highways and other human encroachments.

"EVEN WITHOUT the Solar Max readings—long before this century, in fact—we've known that changes occur in the sun," I heard from John A. Eddy of the Office for Interdisciplinary Earth Studies in Boulder. He is one of the world's leading solar historians.

"Chinese, Korean, and Japanese court astronomers recorded spots on the sun at least 2,000 years ago. Galileo saw them in his first telescope in 1610. The fact that the spots varied on a regular cycle wasn't recognized until 1843, by a German amateur astronomer, Heinrich Schwabe. Their number and position changed, and in some years there were more of them, in other years and decades, many fewer.

"We know today," Jack Eddy went on, "that the spots not only are real but also indicate massive changes going on in the sun. As the spots cross its face—moving with the rotating

Summer briefly turns the plains of northern Canada into one of the world's largest wetlands. While wet soils emit some methane, plants capture CO_2, which is later stored as peat. The plants and peat insulate the frozen soil beneath.



CONSULTANTS: ARTHUR H. LACHENBRUCH, U. S. GEOLOGICAL SURVEY; KIM M. PETERSON, CLEMSON UNIVERSITY; TROY L. PÉWÉ, ARIZONA STATE UNIVERSITY

A warmer climate could devastate tundra. Thawing of frozen soil and permafrost would lead to massive drainage, causing the land to subside (above). The ecosystem could no longer support gray wolves, caribou, and millions of migratory birds. In a perpetuating cycle, that devastation itself would worsen global warming. As permafrost thawed, it could release huge amounts of ancient, ice-locked methane; additional CO_2 would be released to the atmosphere as peat bogs decomposed.

TUNDRA AND BARREN LAND
TAIGA (Boreal forest)
C A N A D A
DISCONTINUOUS PERMAFROST
POTENTIAL RANGES
PRESENT NESTING HABITAT OF KIRTLAND'S WARBLER
U N I T E D S T A T E S
PRESENT RANGE OF SUGAR MAPLE
PRESENT RANGE OF AMERICAN BEECH
PRESENT DISTRIBUTION OF FLORIDA PANTHER
VULNERABLE COASTAL WETLANDS
0 500 km
0 500 mi

Forests migrate just as animals do, only much more slowly. Over a century a species like the American beech, which is dependent upon birds and mammals for dispersing its seeds, can advance perhaps 20 miles. Yet by then its range — defined by temperature and soil moisture — will have shifted hundreds of miles to the north, according to some warming predictions (map, left). Beech trees could virtually disappear in the U. S. Sugar maples, valued for furniture and foliage as well as syrup, may face the same fate.

TREE MIGRATION CONSULTANTS: MARGARET B. DAVIS AND CATHERINE ZABINSKI, UNIVERSITY OF MINNESOTA
COASTAL WETLANDS CONSULTANT: STEPHEN P. LEATHERMAN, UNIVERSITY OF MARYLAND

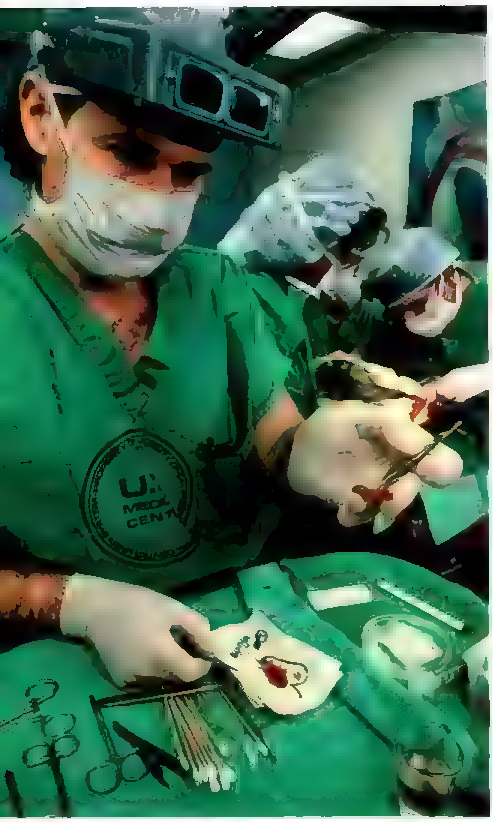
NGS CARTOGRAPHIC DIVISION
PRODUCTION: ELLEN J. LANDSMAN, JAMES E. McCLELLAND, JR., MICHELLE H. PICARD
MAP EDITOR: JOHN T. BLOZIS

Preview of a crisis

WARMER CONDITIONS than any felt in the past 100,000 years will confront plants and animals if the earth warms by 3°C by 2050, as some climatologists predict. Such a climate change would be ten times faster than any since the last ice age, hugely stressing the web of life. Soil moisture patterns could shift radically, as could relationships between predators and prey.

body—they affect the total energy the sun sends out into space."

As outward evidence of magnetic disturbances on the sun, the spots sometimes herald solar storms or flares, which can disrupt short-wave radio communications on earth or with satellites and cause destructive surges in high-voltage power networks. In March 1989 a massive solar flare disrupted the electric-power grid of much of eastern Canada and produced spectacular shimmering lights in the ionosphere (pages 96-7). The pulsating red, green, and white curtains called the aurora borealis, or northern lights, were seen as far south as Florida and Texas.



DO SUNSPOTS affect the planet's weather and climate? There have been times in past centuries when sunspots were very scarce—or missing entirely, if lack of any record of them can be believed. One notable period was between 1645 and 1715, the so-called Maunder Minimum, named for a British solar astronomer of the 19th century. The coincidence of their absence with the particularly cold period of the Little Ice Age, which gripped Europe from the 1400s to the 1800s, has long intrigued solar scientists.

Eddy and other astrophysicists point to the Maunder and a sequence of earlier minimums as the clearest evidence of long-term change in the sun's total activity, perhaps in cycles longer than the principal periods of 11 and 22 years, and of a possible connection between sunspots and the earth's climate.

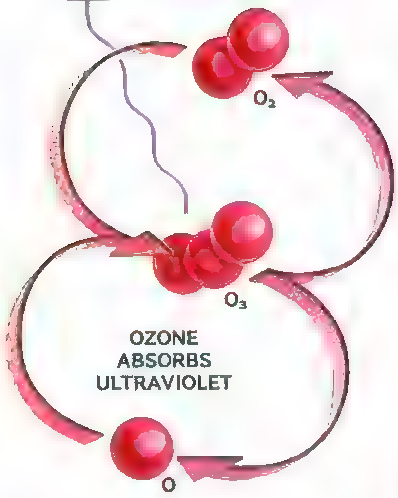
The evidence remains circumstantial. "But there can be little doubt," Eddy has written, "that variability is a real feature of the sun. The challenge now is to understand it."

One clue to sunspots and their effects on the earth lies in an unlikely repository—the record of weather changes locked in the growth rings of trees. At the Laboratory of Tree-Ring Research of the University of Arizona at Tucson, director Malcolm Hughes and others showed me the 8,500-year consecutive tree-ring record acquired by that pioneering laboratory in decades of work in the U. S. Southwest. Periods of faster and slower growth in tree rings since the 17th century have been linked to wet periods and droughts—and possibly to the sunspot cycle.

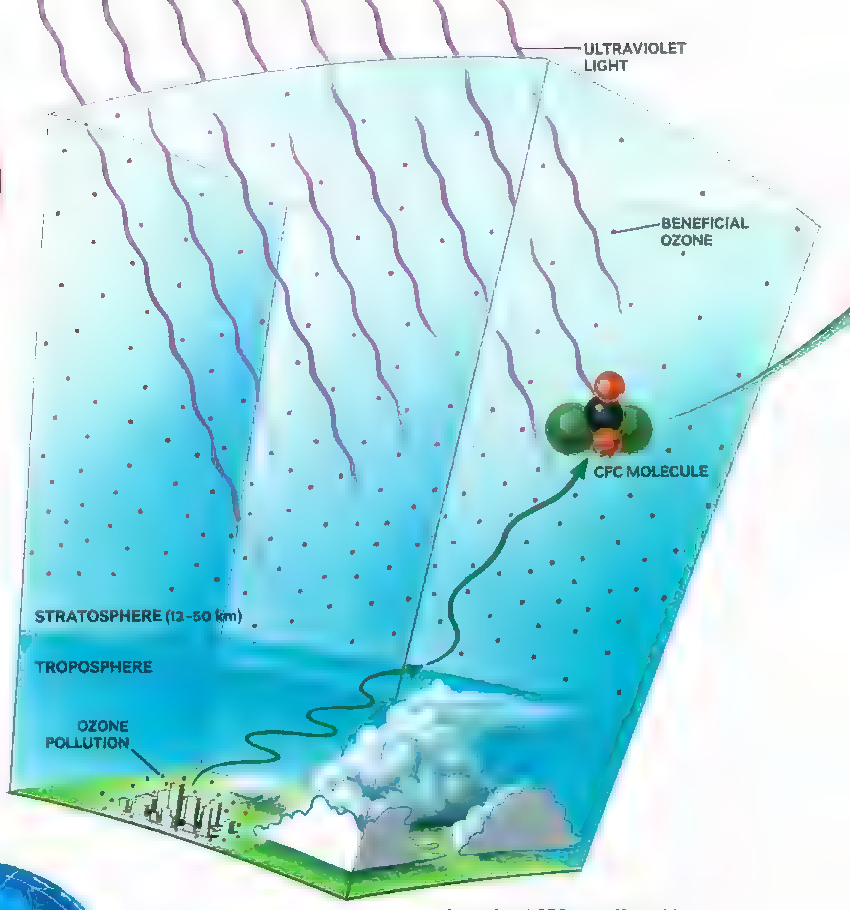
"There is clear variability in much of this tree-ring record, in a pulse close to 20 years," Hughes said. "Scientists such as

"Mad dogs and Englishmen go out in the midday sun," wrote playwright Noël Coward. But they pay a price. More than 60 percent of the sun's ultraviolet light (UV) strikes between 10 a.m. and 3 p.m., increasing the risk of tissue damage. A Memorial Day visit to Virginia Beach (above) sent Sue Polinsky to the hospital with first-degree burns (right). UV's cumulative effects can cause both fatal and nonfatal skin cancers, which are fast increasing in the U. S. Dr. Roy Grekin of the University of California, San Francisco, holds a tumor he just removed from a patient's ear (left).

KAREN KASMAUSKI (ABOVE)



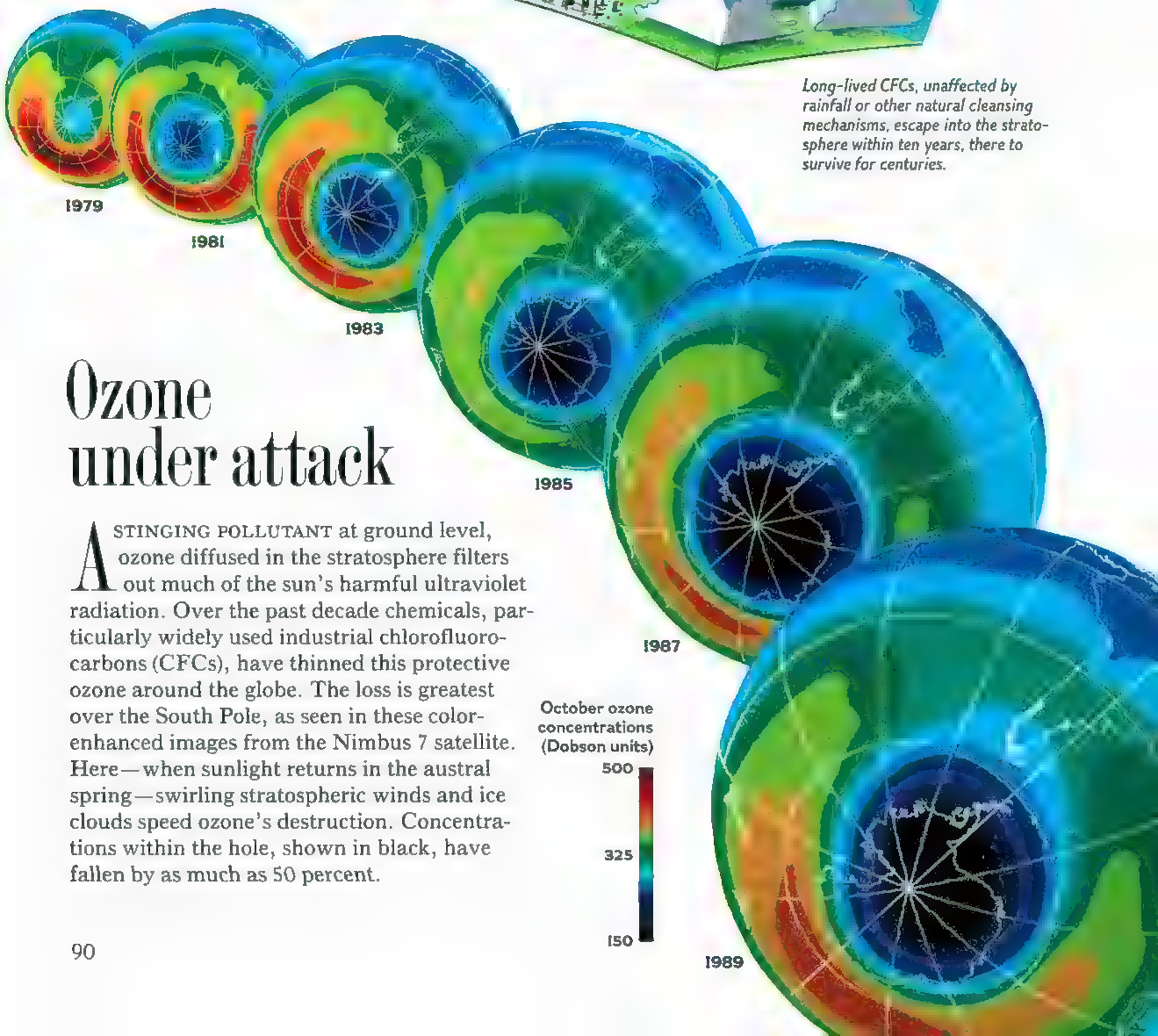
Ozone — O_3 — is scarce, even in the stratosphere where it is most concentrated. But each molecule counts. Highly unstable — three is a crowd — an ozone molecule readily splits up when hit by ultraviolet radiation (diagram above). The energy of the life-damaging UV rays is thus converted into harmless heat and never reaches the earth. The breakup leaves a free oxygen atom — O — and an oxygen molecule — O_2, the stuff we breathe. The O and O_2, in an ongoing cycle, recombine to form new ozone molecules.

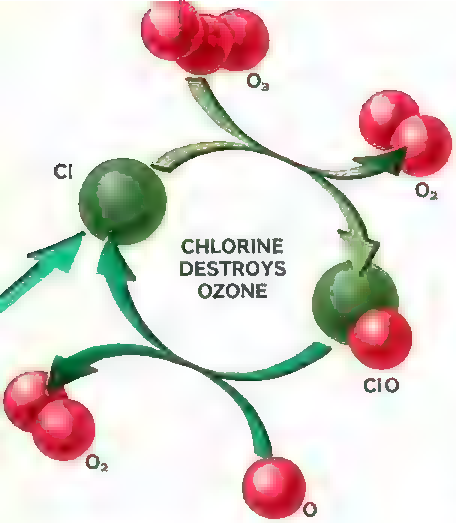


Long-lived CFCs, unaffected by rainfall or other natural cleansing mechanisms, escape into the stratosphere within ten years, there to survive for centuries.

Ozone under attack

A STINGING POLLUTANT at ground level, ozone diffused in the stratosphere filters out much of the sun's harmful ultraviolet radiation. Over the past decade chemicals, particularly widely used industrial chlorofluorocarbons (CFCs), have thinned this protective ozone around the globe. The loss is greatest over the South Pole, as seen in these color-enhanced images from the Nimbus 7 satellite. Here—when sunlight returns in the austral spring—swirling stratospheric winds and ice clouds speed ozone's destruction. Concentrations within the hole, shown in black, have fallen by as much as 50 percent.





When a UV ray strikes a CFC molecule, it releases a chlorine atom—Cl—which then attacks ozone molecules in a catalytic reaction (above). The chlorine breaks the ozone—O_3—into ordinary oxygen—O_2—and combines with the free atom of oxygen to form chlorine monoxide—ClO. This is then stripped of its oxygen atom by another free oxygen atom that joins it to become ordinary oxygen. The chlorine atom is left intact to repeat its destruction. It may do so 100,000 times before it is finally neutralized.

Murray Mitchell and my colleague Charles Stockton see this pulse as a combination of the sunspot cycle and a lunar cycle of 18.6 years and relate it to cyclical droughts in the West, such as the 1930s Dust Bowl.

"More than that, varying amounts of a carbon isotope in the tree rings—carbon 14—may be a clue to long-term changes in solar radiation and its effect on the earth's atmosphere," Hughes told me.

"The irregularities in the carbon-14 production rate are known as the Suess wiggles, for Hans E. Suess, their discoverer. They are extremely important in calibrating and correcting the carbon-14 calendar used to date ancient events from remnants of organic materials, such as ancient wood or bones."

Other theories of sunspot-climate relationships have come and gone, but no true "smoking gun" had been found—until the mid-1980s. Then a German atmospheric physicist, Karin Labitzke of the Free University of Berlin, together with Harry van Loon of NCAR in Boulder, published a remarkable fit between reversing winds in the stratosphere, polar air temperatures, and the sunspot cycle. If their discovery is confirmed, it will indicate a direct link between sunspots and the atmosphere of earth—a possibly crucial connection. The work has been cited as among the most significant now being pursued at NCAR.

One connection may be a better understanding of the ozone hole in the so-called polar vortex over Antarctica each winter, a giant whirlpool of stratospheric winds.

Chameleons darken after being injected with a melanin hormone synthesized by a team led by University of Arizona biologist Mac Hadley. The substance may one day offer fair-skinned people greater protection against skin cancer.

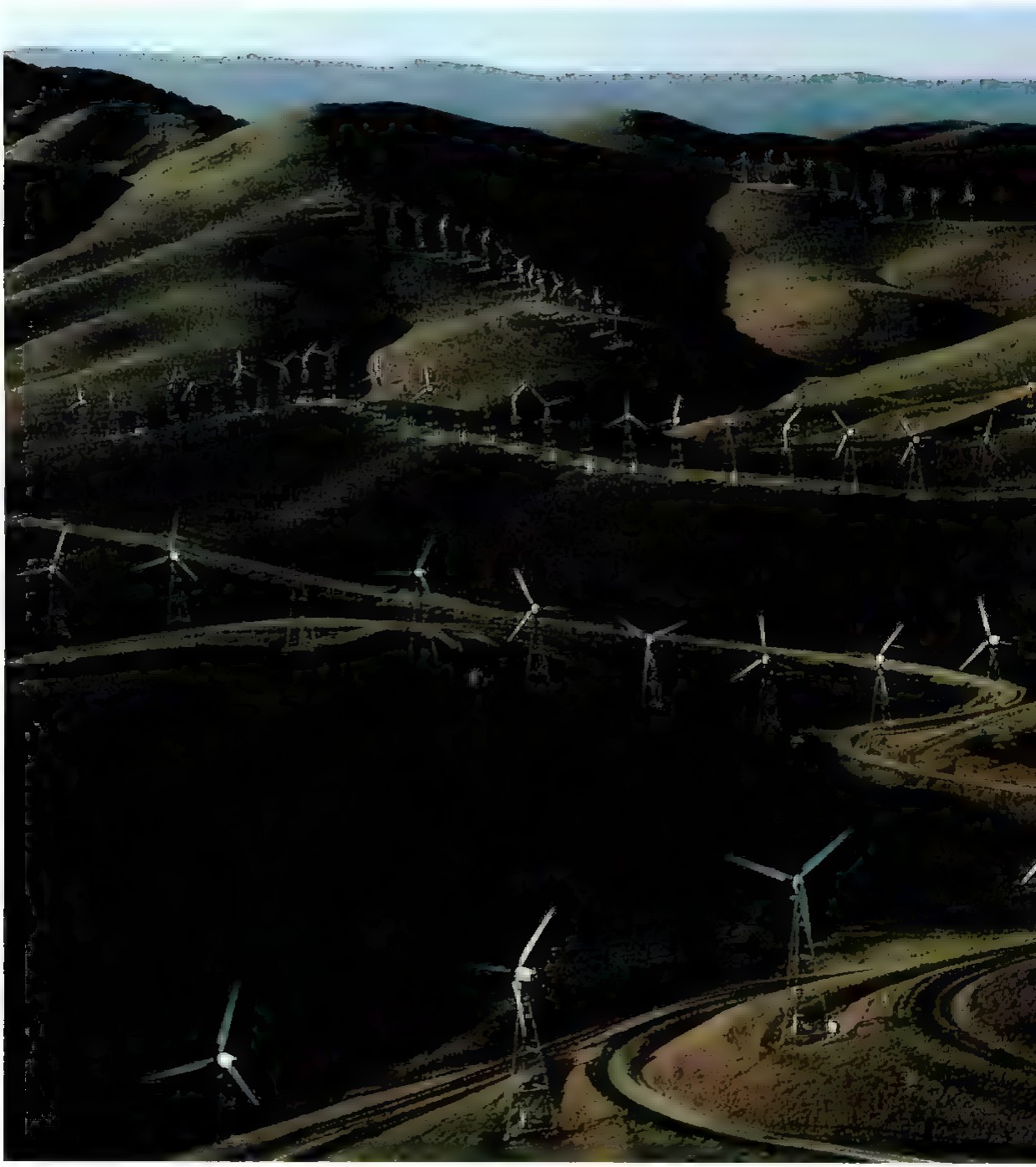
PAINTING BY MARK SEIDLER
OZONE CONSULTANT: MARK R. SCHOEBERL, NASA/GODDARD SPACE FLIGHT CENTER (GSFC)
CHEMISTRY CONSULTANT: MARTIN R. FELDMAN, HOWARD UNIVERSITY

TOTAL OZONE MAPPING SPECTROMETER IMAGES PROVIDED BY NASA/GSFC

IN THE MID-1980s the world became suddenly aware that the protective ozone shield in the atmosphere was in danger—was, in fact, greatly depleted in a huge "hole" over the frozen wastes of Antarctica. The mysterious stuff called ozone, which until then was known to the public chiefly as an acrid, lung-burning element of smog in overcrowded cities, was being destroyed in the stratosphere by chemicals made and released in the 20th century by humans.

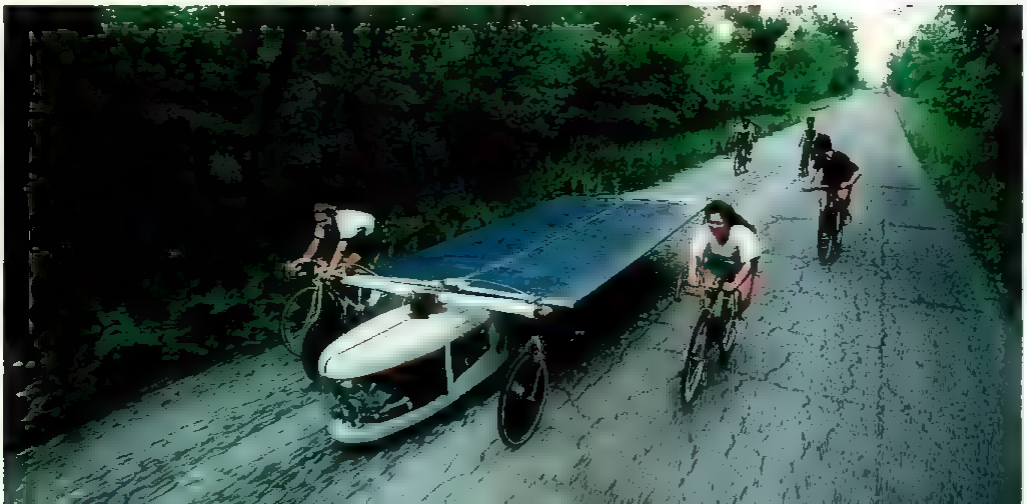
Ozone is a variant form of oxygen—the most life-sustaining gas of all. Under the intense ultraviolet bombardment from the sun at the upper reaches of the earth's atmosphere, normal two-atom molecules of oxygen are split into single atoms—O rather than O_2, in chemists' terms. Some of these single oxygen atoms rejoin with O_2 molecules to form ozone—O_3. The amount in the stratosphere is very scant, less than ten parts per million (at sea level the layer would be about as thick as a pane of window glass), but that layer is enough to stop most of the sun's dangerous ultraviolet rays from reaching the earth's surface, 10 to 30 miles below.

The possibility of ozone destruction by man-made chemicals had been predicted as early as 1974 by two farsighted researchers, F. Sherwood Rowland and Mario J. Molina, at the University of California at Irvine.



Propelled by energetic winds and one of the world's strongest economies, California produces 85 percent of the planet's wind-generated power. The state's 17,000 wind turbines, like these in Altamont Pass, provide enough electricity—about one percent of the yearly total—to meet all the residential needs of a city the size of nearby San Francisco. Experts say wind power could eventually produce 10 percent of the United States energy supply.

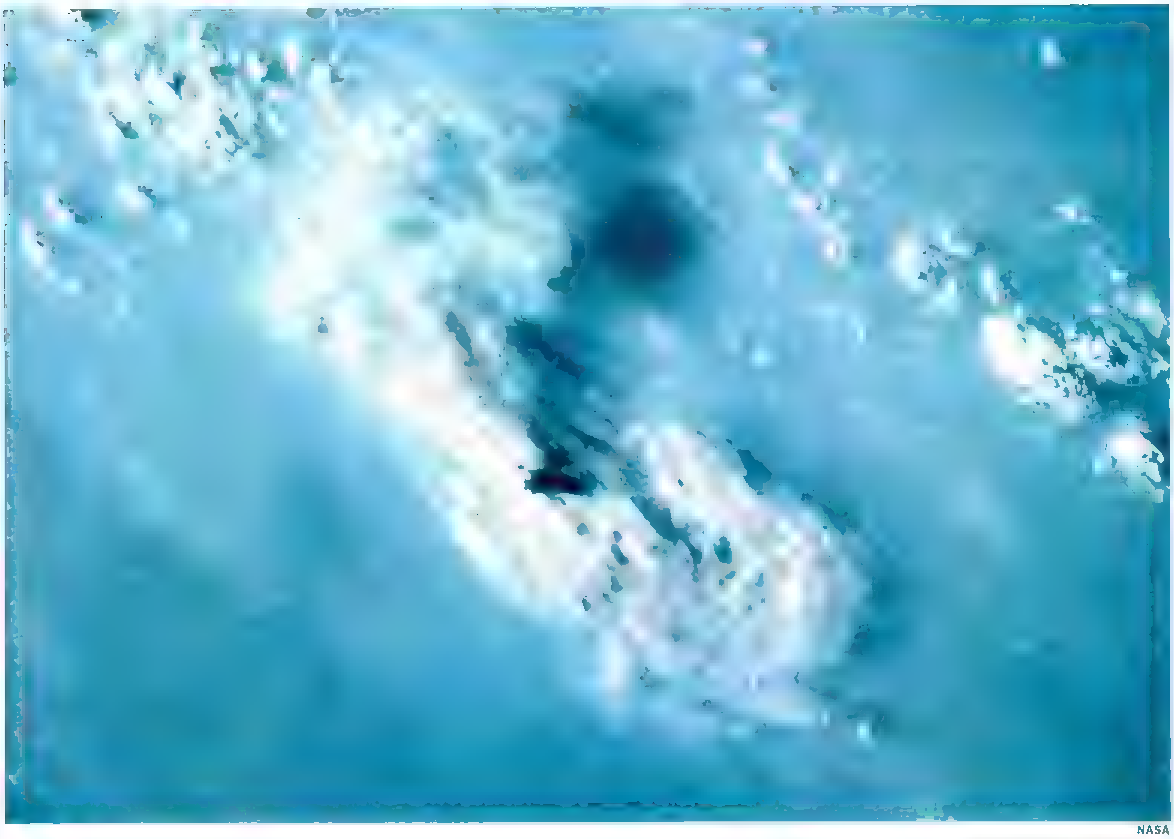
Another 10 percent of the supply could come from solar energy, including photovoltaic cells. Today such cells power everything from calculators and demonstration cars (right) to remote telecommunications stations and water pumps.



Certain industrial gases dubbed CFCs—chlorofluorocarbons—are so highly stable and inert that they do not react with other substances in nature. Thus they have long been used as the coolants in refrigerators and air conditioners, as the propellants in aerosol cans, in making foam-plastic objects such as coffee cups and fast-food containers, and as solvents for cleaning electronic circuit boards and computer chips. But there could be great danger, warned Rowland and Molina, when those same long-lived gases drift to the upper layers of the atmosphere.

In that same region where ozone is created by solar bombardment, the CFCs could break apart, they postulated, freeing chlorine atoms that could attack and destroy ozone molecules by the billions. If this were to deplete the ozone layer around the whole world, it would put all mankind at risk.

The hazard was judged serious enough for the United States



NASA

to ban CFCs from aerosol cans in the late 1970s. But CFCs are still produced for other uses, and millions of tons more lie waiting to be freed from scrapped refrigerators and air conditioners.

Then came the first startling report by British scientists in 1985 of an Antarctic ozone hole, and a rash of scare stories blossomed in the world's press. Emergency field studies of the stratosphere above Antarctica were mounted by U. S. science agencies, led by NASA, NOAA, and the National Science Foundation. In 1987 an ER-2 aircraft, capable of flying to 70,000 feet in the stratosphere, and a DC-8 jammed with instruments flew from Punta Arenas, Chile, near the tip of South America, out across the ice-locked Antarctic continent.

The hole was real; the ozone had dropped by 50 percent (page 90). Its destruction was confined within the rotating swirl of winds in the polar vortex. And it was caused by a chemical reaction, not some unfathomed atmospheric phenomenon. The reaction seemed to occur in the presence of thin polar ice clouds that form in the intense cold of late winter, just before the sun returns to strike the polar latitudes.

Less than a year later, in September 1987, more than 40 nations sent delegates to Montreal, Canada. The industrialized countries agreed to reduce production of CFCs by 50 percent by 1998. A June 1990 revision called for a 100 percent ban by the year 2000, with a ten-year time lag for less developed nations.

Does another ozone hole develop over the Arctic in its winter? If the Northern Hemisphere, far more populous than the Southern, is also being depleted of its ozone umbrella, it might pose a far more serious emergency.

The same team of atmospheric scientists and computer experts, including Robert Watson of NASA and Adrian Tuck and Susan Solomon of NOAA, spent 45 cold, bleak days in January and February 1989 in the North Sea port of Stavanger, Norway. There the same ER-2 and DC-8 flew 28 missions, from the northernmost airstrip that could safely be used, to take readings from the air of the polar Arctic.

It took a year to analyze all the data. In March 1990 the scientists published their answer. The polar vortex and ice clouds existed also in the northern stratosphere, though not to the same extent as in the southern. Ozone was being depleted in the Arctic as well, by as much as 15 to 17 percent at some altitudes.

Over the heavily populated mid-latitudes of the globe, the researchers believe, winter ozone levels may have dropped in the past decade by as much as 4 to 6 percent. And even if all CFC production worldwide were to be halted—an unlikely possibility even to the signers of the Montreal Protocol—the amount already existing and waiting to be released to the atmosphere would mean a continuing ozone drop for decades to come.

A smoke signal seen by space shuttle astronauts in 1988 reveals burning of Brazilian rain forest. Used to clear land for farming and ranching, such fires release water vapor, methane, nitrogen oxides, and carbon monoxide, as well as CO_2. The dark, towering feature is the shadow of hot gases rising through a hole in the white, cloud-like pall of smoke. Such a pall over the United States would blanket everything east of the Rockies. Astronauts have seen similar formations over burning grasslands in Madagascar, Australia, and Africa.

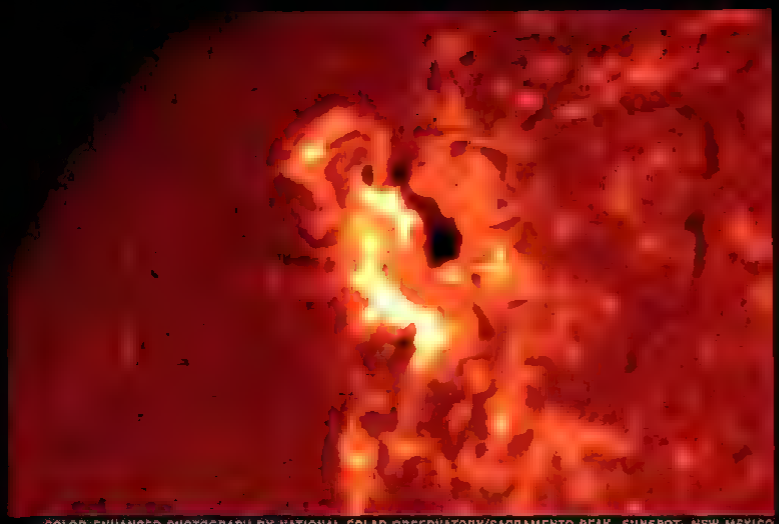
Burning wood provides essential energy in many developing countries. African nations, on average, gather 70 percent of their energy from wood. With populations soaring, pressures grow ever more acute to burn trees for energy and to clear lands for farming.

THE WORRY IS that stratospheric ozone forms the earth's principal shield against dangerous ultraviolet radiation from the sun. This short wavelength light, below the range of human visibility, kills many forms of life—bacteria, for example, which is why it is used for sterilizing surgical instruments and protecting many foods. But ultraviolet also kills beneficial forms of life, and it can affect the life cycle of many plants, both on land and in the seas.

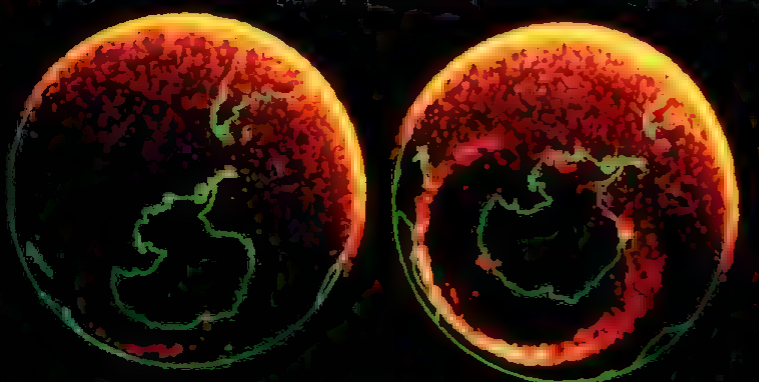
Middle and long wavelengths of UV cause not just tanning and extreme sunburn in human skin but the most prevalent forms of skin cancer. They also can cause cataracts in the eyes and injure the immune responses of skin, which protect us from many harmful, even deadly diseases.

The Environmental Protection Agency issued a risk assessment in 1987, predicting that for every one percent drop in global ozone, there would be a one to three percent increase in skin cancers. Global ozone has dropped at least 2 percent in the past ten years, EPA said, leading to possibly four million added cases of skin cancer. In the past ten years alone, dangerous skin

The sun's fireworks



COLOR-ENHANCED PHOTOGRAPH BY NATIONAL SOLAR OBSERVATORY/SACRAMENTO PEAK, SUNSPOT, NEW MEXICO

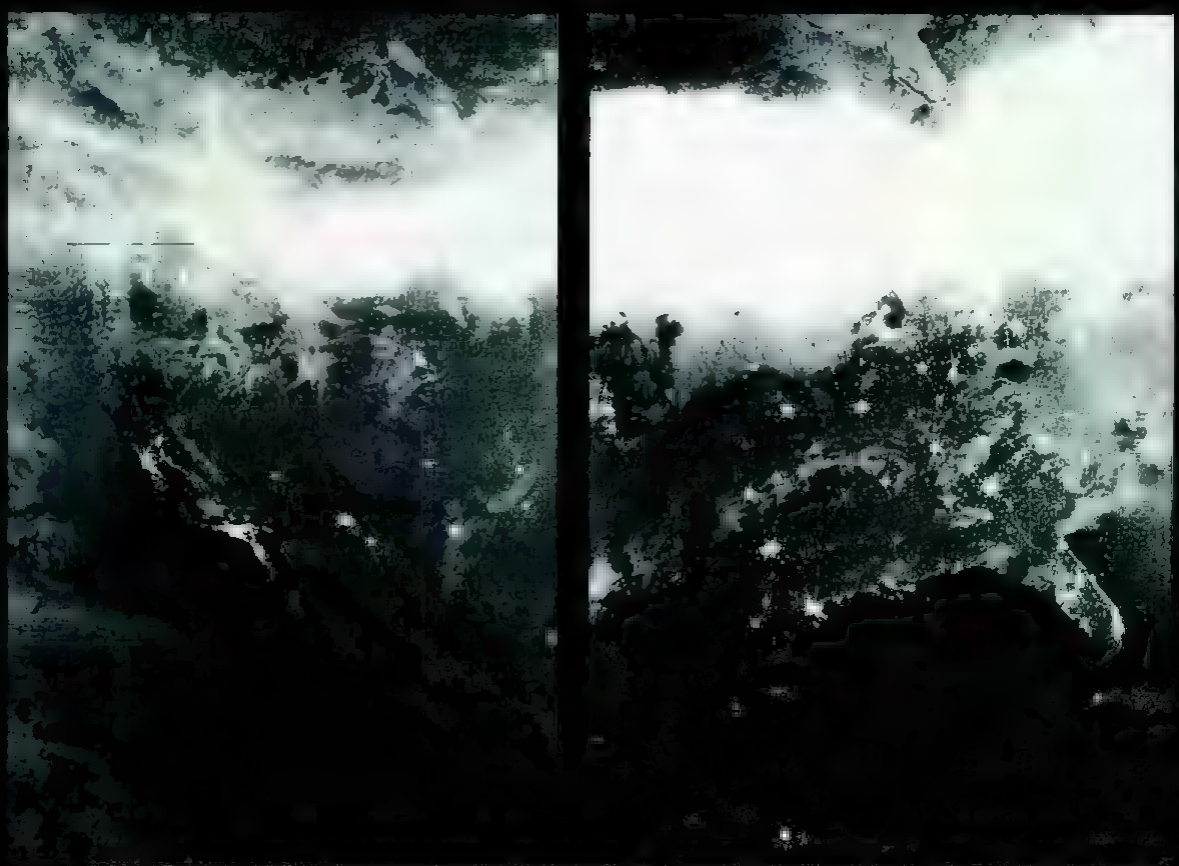


LOU FRANK AND JOHN CRAVEN, UNIVERSITY OF IOWA

ITS CYCLICAL seething near a peak, the sun emitted a spectacular flare on March 10, 1989 (left), part of a series that showered the earth with charged particles and X rays. The event produced shimmering auroras, as seen two days later in Troy, New York (right).

While the main auroral belt stretched across the northern U. S. and southern Canada, as captured in these satellite images (below), the northern lights were seen as far south as the Florida Keys. In the Southern Hemisphere an auroral band (left, at right) far stronger than usual ringed the geomagnetic pole.

The solar storm nudged satellites out of orbit, garbled radio communications, and caused electrical outages across much of eastern Canada.



F. RICH, GEOPHYSICS LABORATORY, HANSCOM AIR FORCE BASE, MASSACHUSETTS, AND J. SCHMIDT, GLOBAL WEATHER CENTRAL, OFFUTT AIR FORCE BASE, NEBRASKA

JULIE CARRAGAN

cancers have risen by 50 percent. Because of the long latency periods after exposure, doctors believe that case numbers will escalate even faster in coming decades.

As the public and bodies politic become ever more aware of these issues and hazards to our home planet, the fundamental question remains: What can be done to safeguard our future?

Much is being proposed, both in this country and in international conferences and discussions among heads of state. Some scientists worry that not enough is yet known about the atmosphere and climate systems to justify spartan proposals of sacrifice and denial. Others counter that *something* must be done before it is too late.

One ambitious effort is the International Geosphere-Biosphere Programme (IGBP). In 1992 it will begin a 10-to-20-year study of the planet, a massive, coordinated follow-up to the historic International Geophysical Year of the mid-1950s.

In this country, planning has been taken on by the National Academy of Sciences and a federal committee whose members include NASA, NOAA, the Environmental Protection Agency, the Departments of Energy, Agriculture, and Defense, the National Science Foundation, and other agencies. Each has its own projects, such as NASA's Mission to Planet Earth, a proposed 15-to-20-billion-dollar program to study the planet from space platforms to be launched beginning in 1998. The President's budget for fiscal 1991 includes an additional billion dollars for pursuing such research efforts.

NASA's chief scientist for global change, Ichtiaque Rasool, in mid-1989 cited to me some of the basic hard facts on which the world's climatologists largely agree:

- The trace gases in the atmosphere—carbon dioxide, methane, nitrous oxide, CFCs—are rising rapidly. They are already at the highest levels of the past 160,000 years.
- These gases incontrovertibly alter the earth's radiation balance through the greenhouse effect.
- Average global temperature has risen about one degree Fahrenheit in the past century, though not steadily.

But will this unusual warmth continue? Or will cooler-than-normal seasons or years return? And what is "normal"?

It is the central uncertainty about natural versus man-made forces in the climate system that causes scientists and politicians alike to hedge their concerns. It is tempting to ask: If nature will correct what we do to the atmosphere, must we give up our profligate ways?

As evidence mounts, the answer seems increasingly clear: We are the wild card in nature, in our ever increasing numbers. "Humankind has become a more important agent of environmental change than nature," Frank Press, president of the U. S. National Academy of Sciences, said bluntly at an international meeting of the Group of Seven industrial nations in Paris in mid-1989.

And what we are doing to the earth's atmosphere, to the blue planet on which we live, is not merely ominous. It may already be beyond correction. □

PER-ANDRE HOFFMANN

In one of nature's most elusive displays, a green flash caps the solar disk as the atmosphere scatters last light over a Norwegian woods. If predictions of extreme warming at high latitudes prove true, Norway's forests may be in jeopardy.

By DAVID ROBERTS Photographs by JOSÉ AZEL
CONTACT PRESS IMAGES

Poised hundreds of feet above his village, a Dogon climber lowers a goatskin full of bird dung, valuable as fertilizer, to the base of Mali's Bandiagara Cliffs. The Dogon's ways have changed little over the centuries. They are like the wild grass whose name they share—survivors in a dry and rugged land.

Below the Cliff of Tombs

Mali's Dogon

Braving dusty harmattan winds that blow from the Sahara, a woman from the village of Youdiou draws water from a well on the Gondo Plain. Her work starts just before dawn. She fills her hours pounding millet

—the staple of her people—preparing meals, caring for her children, chopping firewood, making pottery, and brewing beer. Soon she will sow the next season's millet, for the arrival of harmattan means the rains are on the way.

"What wisdom will the fox bring?" wonders Amaguimé Dolu, a diviner in the plateau village of Bongo. For generations Dogon diviners have ventured out at sunset to trace in the sand grids and symbols representing questions

put by villagers. After leaving a strategically placed offering such as groundnuts to attract the fox, which the Dogon believe to be an oracle, the diviner returns at sunrise to interpret the path of its paw prints.

I STEPPED GINGERLY among the human bones, which pressed around my ankles in the ocher dimness. One hundred feet up an overhanging cliff, in a cave that would accommodate no more than ten living people, 3,000 skeletons had been packed like so much landfill. Dusty bits of cloth, bearing faded indigo checkwork, lay snagged in the talus of ribs and femurs.

Who were these dead? How had they reached this graveyard in the sky? Where had they come from? Why had they settled in this harsh, sunbaked part of Africa where the Niger River cuts through the Sahel?

The bones belonged to the Tellem, a people who first appeared in the 11th century and vanished 500 years later, leaving only these cliffside graves, some mud-brick granaries they built into the caves, and a variety of exquisite funeral statuettes and other burial objects as their enigmatic legacy.

Many of the Tellem caves lie all but out of reach, honeycombing a high, sheer sandstone escarpment called the Bandiagara, which curves across 120 miles of central Mali, in what was once French West Africa. One of the last wildernesses explored by Europeans, this land of the cliffs has sheltered a succession of Africans dating back to at least 300 B.C. The earliest known people, whom archaeologists call the Toloy, seem to have vanished after a few brief centuries. More than a thousand years passed, and the Tellem arrived; they, in turn, disappeared during the 16th century, supplanted by yet another, unrelated people, the Dogon of today, who live in several hundred villages scattered over an area of 5,000 square miles.

With photographer José Azel, I had come to Mali to explore the Tellem's caves and spend time among their successors. The Dogon, numbering some 300,000, are farmers who live by the ancient rhythms of their ancestors, little touched by modern ways. Although a few Dogon settlements have been opened to tourists, most exist as they have for centuries, tucked away in Mali's high plateaus and hidden valleys, secluded from white explorers, even from other Dogon. The evidence of that solitude can be heard in 35 Dogon dialects, which often baffle interpreters venturing a mere 30 miles from Sanga, a major settlement.

Drenched in morning light, the Bandiagara escarpment (opposite) is home to the Dogon. Nearly 600 years ago they settled on the plateau and the scree slope below. High on the cliff walls the Dogon found old granaries and burial caves of the Tellem people, thought to have great magic. Dangling from an overhang, the author looks into a cave (above) containing the remains of 3,000 Tellem. Unrelated to the Dogon, the Tellem vanished in the 16th century after 500 years of occupation.

I hoped to learn something of the mysterious Dogon and their remarkable predecessors, perhaps the finest climbers of the ancient world. As a mountaineer, I had spent years exploring the harsh country of the American Southwest, where the Anasazi Indians had lived among sandstone cliffs strikingly similar to those of the Tellem and Dogon half a world away. In the wilds of Mali, I suspected, were prehistoric ruins just as imposing as those of the Southwest. I was not disappointed.

From the cave of 3,000 skeletons I watched two Dogon women at their daily chores. They carried water jars on their heads and chattered easily, walking barefoot on a rocky path shaded by the occasional acacia tree. In Dogon country the mornings are slow and hazy, the daily rounds timeless. I watched lean men working alone on the edge of town, chopping at tiny plots of millet, sending

up clouds of dust. And everywhere I heard women pounding the eternal millet, singing in the cadence of their teamwork.

THE DOGON VILLAGE of Ireli was nearly invisible from a distance. Walking toward it, all I saw was a rusty landscape of rocks, grass, and baobab trees. Gradually the outlines of Ireli shimmered into view: sand-colored houses, thatched roofs, and stony lanes. The granaries, both strange and beautiful, were square towers crafted out of mud and straw, set on low stilts; their cone-shaped roofs looked like caps set at a jaunty angle. There were more granaries than houses.

A man dressed in a shin-length cotton tunic crossed my path on his way out of town. Without breaking stride, he hailed our interpreter, Oumar, with an elaborate greeting that touched on Oumar's health and that of his family and faded as the stranger went away, still conversing. We trudged into his village, where naked boys and girls ran out to greet us, screaming their favorite French phrase, *"Ça va? Ça va? Ça va?*—How goes it?" The shy ones hid behind houses and peeked; the bold ones took our hands, leading us through narrow lanes where chickens flapped underfoot and runty dogs yipped. Whenever we paused, obliging boys knelt in the dirt and began pulling the irksome nettles called *krem-krem* out of our socks.

Here, as elsewhere along the Bandiagara, soil is so precious that some natives build their houses on top of boulders to save a few square yards for planting. The *ginna,* or family house, is laid out in the shape of a human body, with a circular enclave resembling the head and oblong side rooms dangling like burly arms by a central clearing that looks like a human trunk. At the village center we came upon the *togu na,* the men's shelter common to every Dogon settlement. Inside, in the deep shade, elders loafed on a stone floor and gazed out at us with sleepy disdain. Women were banned from this, the coolest place in town, an open-sided building with a roof of dried millet sheaves eight feet thick. A set of adobe-style pillars, sculptured with skeletal figures representing the eight mythical Dogon ancestors, supported the roof. We passed another house, its facade scored with eerie, undulant columns and decorated with monkey skulls and jewelry set in the plaster wall. This was the home of the village *hogon,* or spiritual leader.

Although Muslim and Christian missionaries have labored among the Dogon for a century or more, converts come slowly. Fewer than half the Dogon have become Muslims, a smaller number Christians. Most cling to their elaborate system of animist beliefs, in which foxes foretell the future and spirits stalk the countryside. The Dogon hate to be away from their villages after dark, and so their hunters, who prowl the night and sleep

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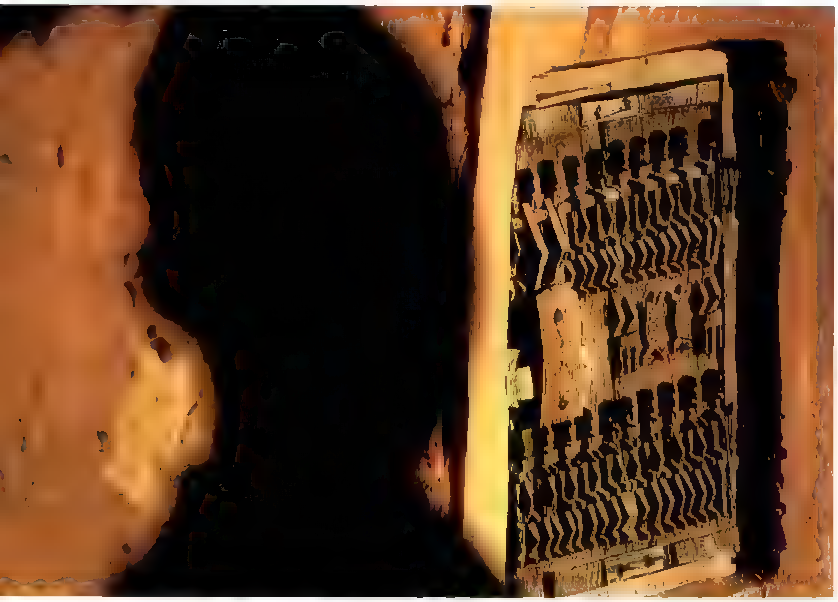
Writer and rock-climber DAVID ROBERTS lives in Cambridge, Massachusetts. This is his first assignment for the magazine. JOSÉ AZEL, whose byline appeared in the GEOGRAPHIC's January 1989 article on the coca plant, lives in East Stoneham, Maine.



Figures carved on the door of a millet granary give a play of shadow and substance. Although the human figures—representations of the owner's family—are simply decorative, the tortoises have mythical power, since they symbolize the departed elders of the family's lineage.

Despite the Dogon's isolation, most of their traditionally carved granary doors have passed into the hands of Western collectors.

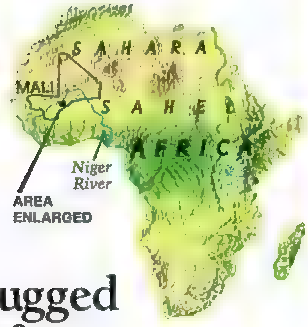
in trees, remain the exemplars of courage.

Even the landscape is imbued with spiritual meaning. Prominent rocks have personal names, as do certain baobab trees such as High Bosom, the Ancestor, and Small Seeds. The Dogon seem to have touched every part of their homeland. As you crash through thickets of thorns on the brushiest of hillsides, you find hand-laid stones marking little-used trails, stairways masoned against the cliffs, chockstones to smooth your step between jagged boulders. And deep in the natural crevices that split the plateau, you come upon notched logs propped upright as ladders, with steps worn shiny by centuries of bare feet.

At the edge of several villages we found gloomy hovels painted with symbols of the Dogon's mythical serpent, Lébé. Grotesque images of women with huge genitals were carved on the walls. Here menstruating women are required to sequester themselves.

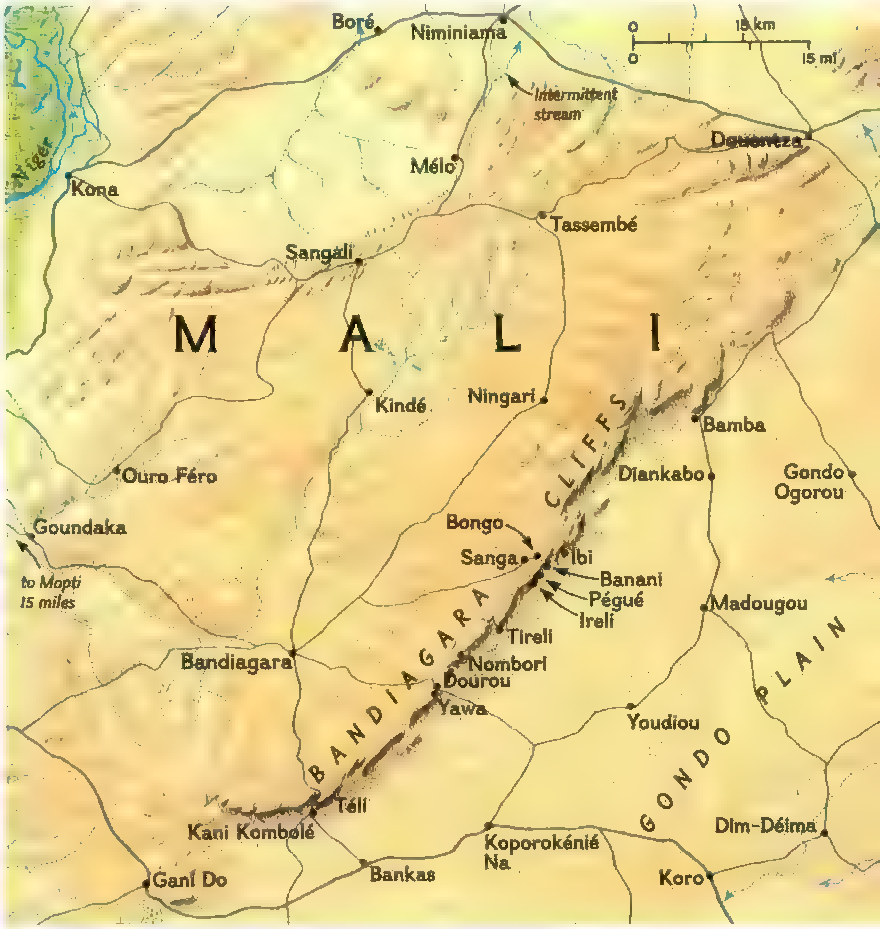
Some Dogon sites have become virtual ghost towns, the cliffside dwellings abandoned for more prosaic settlements on the flats below. In one such place, in part of the old village of Téli, guided by a swarm of boys, I stumbled upon an old woman lying sick on the stones of an otherwise empty alley. As we approached, she screamed, and the boys scattered as before a witch. On another day I puzzled over empty granaries covered with ancestral chimeras in bas-relief; mystic swaths of red, black, and white triangles were painted on the overarching wall. Twice I happened upon caches of tiny blue cups, which outsiders are not permitted to see, for the hogon uses them in funeral rites.

Often Oumar would warn us not to stray from the trail. Waving at some nondescript hollow in the weeds, he would say simply, "It is forbidden." When I spotted a carved wooden object in the scanty grass and reached toward it, Oumar raised a hand and hissed at me: "No! Don't touch it!" The object turned out to be a single-footed seat, used only on that most sacred of occasions, the Sigi. In that ceremony, which takes place every 60 years, the Dogon perform dances and sacrifices to renew their world. The rest of the time, this wayside relic guarded a

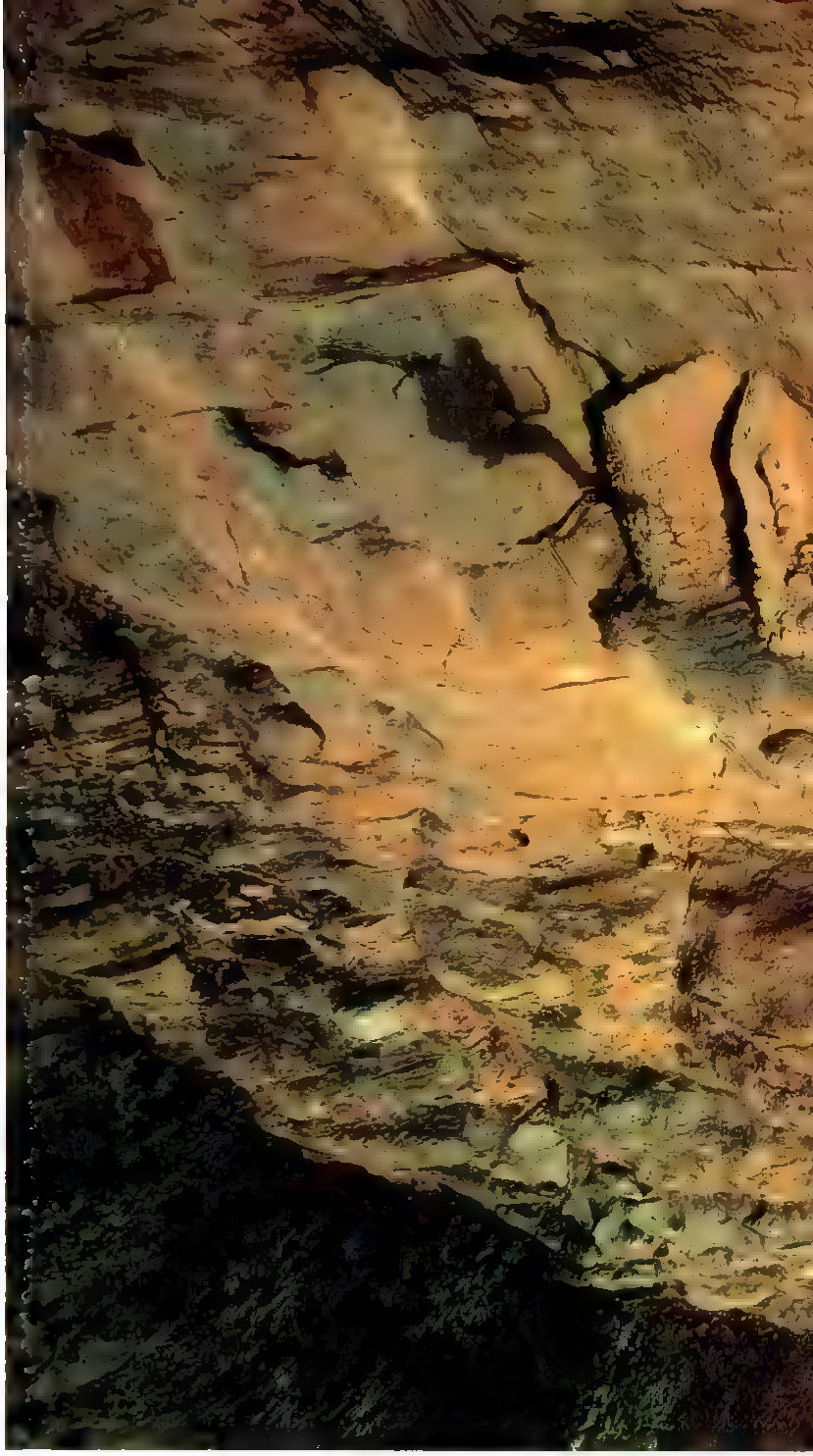


Rugged refuge of the Dogon

Cutting a jagged path across central Mali, the Bandiagara escarpment was recently named a world heritage site for its cultural and natural significance. Since the 15th century the cliffs have served the Dogon as a barrier from attacks by the neighboring Mossi, Songhai, and Fulani. Yet the terrain poses its own challenge: to coax sustaining crops from the arid soil.



NGS CARTOGRAPHIC DIVISION, PAINTINGS BY JOHN A. BONNER (L) AND ROBERT W. TOPE (R)



Spider-like agility helps Dogon climbers reach all but the most inaccessible Tellem granaries (above). There the Dogon bury their dead, having hoisted the body with baobab-fiber ropes.

A climber (left) risks his life to collect guano; it will be traded at the market in Sanga for items such as tools, clothes, and ornaments. Now and then villagers will pilfer Tellem pottery, bracelets, and rare finger bells (right).

locality against evil spirits. From a distance I often saw strange mounds of clay the Dogon consecrate as altars, usually stained with streaks of white or rust, the residue of sacrifices of millet porridge or animal blood. I was forbidden even to approach these sites, but José eventually prevailed upon the Dogon to let him photograph one (pages 116-17).

Faced with constant pressure to tailor their culture to Muslim or Western standards, the Dogon have resisted admirably, even to the extent of keeping their own calendar. A Dogon week has five, not seven, days. Each town has its own market day, which draws buyers and sellers from miles around. In village markets all along the escarpment, they haggle over prices in cramped stalls and alleys that smell of sweat, charred goat meat, dust, and manure. Women dominate the scene. Amused by the presence of strange-looking foreigners, they sit behind their displays and press us to buy bowls of porridge, onion balls, and rubber flip-flops. No market day is considered successful unless it slides in the afternoon toward a drunken fete.

Being a male of any age is the only requirement for entry into the togu na, *or men's house. A thick, millet-stalk roof keeps the low structure cool while men talk, prepare tobacco, or take naps. Elders meet there to discuss village business. The carved posts are often decorated with figures from Dogon mythology and everyday life. In some villages elders deface carvings to prevent their theft.*

Camped near the village well on such a day, we tossed in our tents long after midnight, serenaded by drums and singing, wild laughter, and inebriated taunts shouted back and forth in the gloom. We awoke toward dawn, to the bantering of women as they drew bags of water from the well on long ropes. They saw our cameras, shrieked, shook their fingers, and fled, sloshing water from the bags in their haste.

NO PLACE in the Dogon world is more sacred than one of their own burial caves. When someone dies, the Dogon purge their grief in a luxurious choreography of masked dances. At the end, the dead person, tied to a wooden bier, is run head-high through the village, accompanied by the wailing of women. Then the corpse is raised to a cave in the cliff, hauled up with ropes made of baobab bark.

Often the Dogon use empty caves they have discovered some distance from their homes. But above every village at the foot of the Bandiagara the cliffside is stippled with Tellem burial caves, and the Dogon sometimes appropriate them for their own dead.

To visit a Tellem cave—even one the Dogon have not taken over—you need permission from the chief of the nearest village. This was always a drawn-out exercise in diplomacy. An advance guard of local boys scampered ahead, eager to show the way. We must have seemed like an odd retinue—José, Oumar, myself, and two American climbing assistants burdened by great loops of blue-and-red nylon rope and sacks of jangling gear.

The village chief of Pégué offered us his best seats—a couple of smooth stones in his front yard. Elders gathered around to listen; younger men, girls, and dogs came to watch. With great dignity the chief produced a pipe and smoked it. He gave us millet beer, a mealy yellow liquid that tastes like weak lemonade, served in a calabash.

Through Oumar we made small talk. Had it been a good year? Was there rain? Were the crops abundant? Then we came to the

real question: Might we visit the caves?

The chief, looking dubious, muttered a few words.

"He says it's out of the question," Oumar translated.

The elders frowned. We made more polite talk and drank more beer. A bit later we asked about the caves again.

"The chief says it's OK," said Oumar. But we were required to go with a trusted villager as chaperone, and we had to make a small contribution to the community. I handed over 2,000 Malian francs, the equivalent of eight dollars, and the deal was closed. The chief nodded decisively and stood, and we shook hands all around.

OUR OBJECTIVE was a daunting ledge high in the 350-foot overhanging wall of the Toloy Couloir, a narrow valley that cuts into the escarpment like a nick in the edge of a glass. Instead of scaling the wall from below, we descended from the top, approaching from the plateau on its far side.

Joe Lentini and Matt Hale, our climbing assistants, brought out the gear: a battery-powered drill to make holes in the sandstone for rope anchors, custom-made metal chocks and cams to wedge in the cracks, and walkie-talkies so that climbers could keep in touch with the support crew.

Tied into a chest-and-waist harness, I backed slowly down the steepening slab. It is a scary thing to be lowered off a cliff, and as I moved past the lip of the overhang and suddenly hung free in space, my pulse quickened. The cliff wall, I discovered, was angled in such a way that I would sail past the ledge and dangle helpless beyond it, like a spider on a strand of silk.

I signaled the men on top to hold me in place, stopping my descent. Then I leaned as far as I could toward the rim of the ledge, using a hook lashed to the end of a long stick to push off from a nubbin of rock, and thus started myself swinging in place—a human pendulum swaying above the deep-shadowed gorge. After about 20 swings, I seized the rock lip and scrambled to safe ground.

I tied off my rope and spent an hour exploring this horizontal island in a vertical wilderness, finding a dozen Tellem sites that had never been disturbed. One cave was a small necropolis, open to the sky, in which I counted 15 skulls. Some of the skeletons lay snug in their cotton shrouds as they had for centuries, preserved by the hot, dry climate of the Sahel. Here, as at every Tellem site, I disturbed nothing and carried nothing away.

Reluctantly I signaled my colleagues to lower me all the way to the ground. As I glided slowly down through 150 feet of thin air, I watched my shadow flit across the face of one abandoned Tellem sanctuary after another.

I had come to Mali prepared to believe that the Tellem, climbing barefoot and using ropes made from bark, had ascended these cliffs, which would challenge to the utmost any specialist using modern equipment. But now I realized that the cliff could not be scaled free, even by the finest rock-climber in the world. There was an absence of vertical cracks, by which experts normally attack

A hearty song keeps a steady rhythm for women threshing millet ears with long wooden pestles called kuna-i. *Prepared as the customary main dish, the coarse, bland grain is also used to make millet beer, which the women brew in large clay pots and sell at the market. The money they make is theirs to keep and affords them a degree of independence.*

precipices. The wall was simply too smooth and steep to be climbed. My mind reeled: How had the Tellem done it?

"THEY HAD very strong magic," said Amadomion, a rugged 38-year-old Dogon climber I met in the village of Pégué. Amadomion wore a blue tunic and a tan three-cornered hat, and his chest and shoulders rippled with muscles thickened by frequent climbing. Every village along the escarpment has one or two nervy experts like Amadomion, who had reached many of the Tellem caves the hard way—from the bottom up. He showed me how. Stopping at the foot of a cliff, he gestured 40 feet upward, where a black stick protruded from a small cave.

"That," he said, indicating the stick, "is a *boulin,* placed by the Tellem many hundreds of years ago." It was a climbing aid. You threw a rope over it and hauled yourself up, like a kid in gym class. Farther up, a hundred feet off the ground, was another boulin, a faint black speck on a distant ledge; above that ledge was an enormous ceiling that jutted over the void.

When you reached the first boulin, Amadomion explained, you pulled the climbing rope in after you, edged your way 60 feet to the right on a small ledge, and stopped at a crevice where another rope had been tied in place. It looped 60 feet farther up in a loose arc, free of the overhanging cliff, over the second boulin. Using that second rope, Amadomion could hoist his climbing rope until it was doubled over the upper boulin. Then he shinnied up, trusting his life to a stick wedged in a crack perhaps seven centuries ago.

The reason for this daring ascent? Pigeon dung. Amadomion filled large sacks with handfuls of the fragrant droppings and sold it at the weekly market in Sanga. Dogon farmers prize bird guano as fertilizer.

The Dogon climber's hair-raising explanation provided clues to how the Tellem might have scaled the cliffs, but a major question remains: How had they gotten the boulins there in the first place?

"The Tellem were very strong," said Amadomion, laughing.

"Stronger than the Dogon?" I asked.

"Yes."

He and other Dogon saw no reason to doubt the magical abilities of cliff-climbing pioneers they had never seen.

"Ils étaient les génies—They were genies," said Oumar.

The others told me that the Tellem could make ropes stand on end. The Tellem could fly. They could become giants and take a single step up to the highest caves, then transform themselves into dwarfs to get inside. They could ride horses straight up the cliffs. They could even *talk* their way up the cliffs, they were such powerful orators.

MYSTERY VEILS almost every aspect of Tellem life, but a few things are known, thanks to two decades of extraordinary work by a Dutch archaeological team led by Johan Huizinga and Rogier Bedaux. The team found that, contrary to Dogon myth, the Tellem were neither giants nor dwarfs but men and women of normal height. And there is no evidence that the Tellem lived in the caves; they used them only for granaries and burials.

Most remarkable are the Tellem grave relics: carved wooden headrests (the oldest wooden artifacts yet found in sub-Saharan Africa); eerie, abstract statuettes resembling humans with their arms raised; ceramic pots patterned by rolling cord or cloth across wet clay; iron finger bells, twisted pins, and bracelets; bows, quivers, and hoes broken and entombed with the dead; pieces of a wooden harp and flute.

The Dutch found no sign of old fires in the caves, no trace of Tellem homes, and no clue to how their society was organized. What did the Tellem believe? Who were their enemies? What tales did they tell around their campfires? Who were their heroes? And why, after all, did they go to such enormous effort and risk to build granaries and burial chambers in these caves? The mystery endures.

The standard explanation for cliff dwellings anywhere is defense against enemies, and we know that the Mossi and the Songhai raided the Bandiagara region in the 15th century in search of slaves. Even earlier the great

She has lived by simple means and traditional ways. The indigo garment, the nose rings, the lip ring, and the earrings were customary to the Dogon women who came before her. She wears the key on her necklace for its beauty. Her name is So, and though some of her people are slowly embracing the outside world, she will not forget the generations past.

Invocations to the spirits build a mood of reverence at an annual sacrifice, the bago di, *in Téli. Elders assist the oldest man in the village, whose offering will thank the god Amma for sparing the village.*

Assistants (right) carry a sheep to the altar, where, following a series of incantations, its throat is slit. The blood is drained on the altar (upper right), then buried in sites throughout the village.

Testimony to the solemn deed, an elder's bloody knife precedes him as he emerges from the decorated ancestral house (upper left), a shrine as well as the home of the village's oldest man.

empire of Mali may have driven the Tellem into a defensive reclusion.

But to my eyes the extreme inaccessibility of so many Tellem sites seemed to argue against the needs of defense alone. It ought to be just as easy to hold off raiders from a cave 40 feet off the ground as from a cave 200 feet high, which demands an elaborate approach with ropes and boulins.

Maybe—just maybe—the Tellem undertook the effort for its own sake, because it was clever and beautiful. By the end of our trip I wanted to believe that aesthetics alone had driven the Tellem to their mastery.

THE TELLEM had a fine sense of style, as I learned in a remote Dogon village one cool December day. I was passing the time with four graybeards who gathered in a courtyard to gossip. One was blind, delicately thin, and his left hand shook uncontrollably. Another sat in the Dogon thinker's pose, elbows on knees, hands on head. Another was wrapped tightly in a cotton blanket against the chill. All sat silent for long spells, pausing to spit in the dirt or shoo away noisy children. Through an interpreter I gently prodded the elders to tell me about the Tellem.

"How do I know?" snapped the blind man, who seemed to be the leader. "I wasn't here." Gradually the elders warmed to our curiosity. "Tell them what you really know," one teased. "Don't go making up stories."

Thus encouraged, the blind man finally began to speak, of how the Tellem had once lived in the cliffs but abandoned them to the Dogon, of how the Tellem used magic to fly around, of how the Tellem had eventually moved north from the land of the cliffs, never to be seen again.

During a lull in the talk, another elder produced a package wrapped in cotton cloth. With his thin fingers, he carefully undid it, revealing a pair of hoes, each about a foot and a half long.

"These are from the Tellem, from a nearby cave," the elder said, handing them over. He wasn't selling, just showing me. The hoes had wooden handles whittled in ringed bands; fixed through the head of each stick was a curved iron blade, like the real hoes Dogon use today. These were too small to be functional; perhaps they were ritual objects. The workmanship was exquisite.

Spending less than a day on their task, men in the village of Youdiou put the finishing touches on a roof. It takes only a few minutes to hoist the straw cap into place atop a towering clay granary, where it is tied to internal horizontal beams. The overhanging brim allows rain to drain off the structure, protecting the millet within.

European collectors have come to Mali offering huge prices for grave goods. The most highly prized artifact—a carved Tellem statuette, for instance—can fetch a small fortune. Thus have some Dogon, who once had a healthy fear of the Tellem mortuaries, turned to grave robbing. When you consider the availability of Tellem burial objects and the precarious nature of Dogon life, the temptation is understandable.

Some Malian antiquarians, Oumar told us, once talked two Dogon boys from Ireli into climbing high into the cliffs to recover two Tellem statuettes, which had been kept safe by centuries of taboo. At sunset the boys furtively began their climb. The first boy made it up the rope, reached into the cave to seize one of the figures, and lost his grip. He

plunged toward the earth, knocking the second boy off the rope; both died.

DURING A MONTH traveling along the Bandiagara, I met many Dogon children with the bulging stomachs of malnutrition, and I saw an inordinate number of deaf-mutes. In the village of Yawa I noticed a teenage girl yelling at someone in the distance. She had a vacant look in her eyes and walked in a strange shuffle. With a shock I saw that her ankles were encased in heavy leg-irons, like the ones used to shackle slaves.

"She's crazy," explained Oumar, sending a chill down my back. But I also realized that the shackles may have been humanitarian in an odd way, like the Dogon practice of hobbling their donkeys. At least the deranged teenager couldn't wander into the wilderness or fall off a cliff.

At night in camp we always attracted a throng of youths who stood around mesmerized, watching us drink tea and write in our notebooks. Once, while cooking dinner, I carelessly tossed an empty tuna can to the ground and was saddened to see six or eight boys dive for it, perhaps because they craved a taste of the exotic or because the can itself seemed a precious object.

Besides millet, the Dogon grow rice, sorghum, and the minuscule grain *Digitaria*, which is charged with ritual significance. Beyond the edge of each village, where the Gondo Plain stretches flat and bleak toward the south, lies a network of lovingly tended green fields. Wherever seeds can get a foothold, farmers plant them. Among the talus at the foot of the cliff, I saw patches of millet growing in shallow depressions on top of boulders. Dogon will even carry soil by the bagful to some rocky outcrop near water and there build an artificial field. Walking along the clifftops, in a wasteland of barren red stone, I would often come upon a skimpy terrace guarding a few square feet of dirt from the vagrant winds; each tiny plot was cultivated by its owner, who walked miles to tend it. Silent, muscular farmers plodded at dawn from stream to onion field, shouldering calabashes full of water, which they painstakingly sloshed, little by little, into their precious gardens. When the onions ripened, the Dogon crushed them and formed the pulp into firm green balls, which they traded for goods as far away as Côte d'Ivoire. They also grow cotton, eggplant, peppers, and watermelons. From a land so stony and dry they gather a surprising abundance of wild fruits, berries, and edible plants. They raise cattle for milk and beef, donkeys as beasts of burden, goats, sheep, and chickens for food and ritual sacrifice. Wild game—which once included baboons and even panthers—has almost disappeared, but the Dogon still hunt small monkeys and birds, using flintlock rifles crafted by their own blacksmiths.

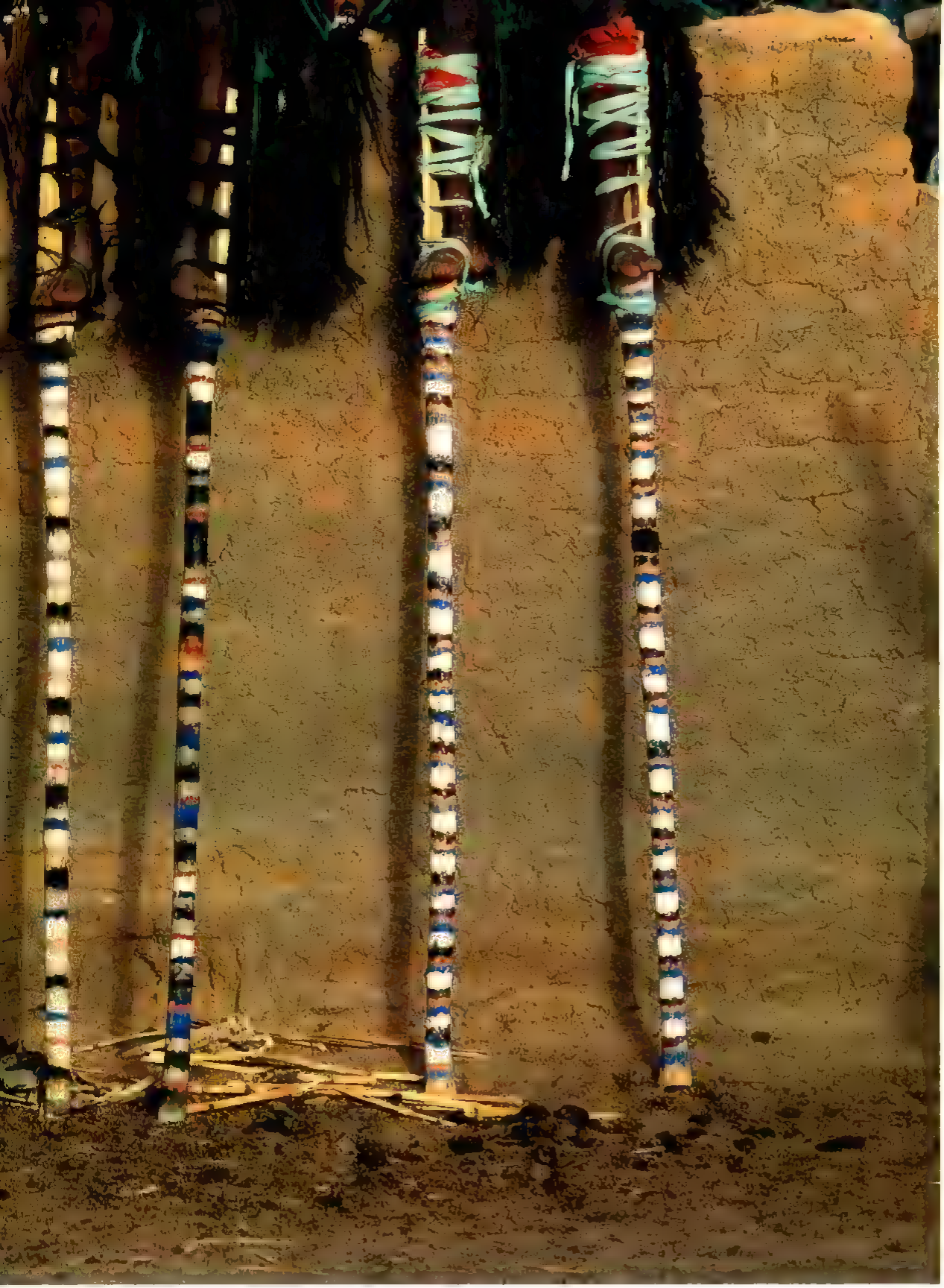
Dependent on the rains, which fall only from June to October, the Dogon suffer terribly in droughts. In the dry year of 1984 hundreds died, and many thousands fled the region, never to return. And during the drought of 1973 Dogon corpses lay along the roadsides; some *(Continued on page 126)*

An erratic mix of geometric forms, the typical Dogon compound is a lesson in utility. For easy access, domed granaries with elfin roofs nestle close to the terraced, rectangular homes. The flat house rooftops are used to dry onions and store pots, calabashes, and baskets. Proximity to the cliffs historically gave Dogon villages a defensive advantage against slave raiders.

Blasts of dust douse spectators watching the kanaga *dancer at a* dama *celebration in Youdiou. Men in masks and stilts take to the dance grounds (left) to mimic creatures from the bush and figures in Dogon daily life.*

The dancer behind the modibo *mask (below right), whose costume was fashioned from cowrie shells and hibiscus fibers (bottom right), represents a Muslim scholar.*

One comes up short as four stilt dancers perch atop a mud wall following a dama performance. They flash eye-catching color as they try to win favor executing difficult steps while tottering high above the



spectators, who have gathered to affirm the spirits of deceased villagers as ancestors. The dance and plumed costumes imitate the characteristics of the tingetange, *a long-legged water bird.*

Onions will soon become profit as a Dogon woman shapes the pounded bulbs into balls that, after being dried in the sun, are trucked as far away as Côte d'Ivoire and sold as an ingredient for sauces.

Introduced by the French after the First World War, onions are a major cash crop. In the early days women drew water from deep, wood-framed community wells (bottom left) and carried it in large pots balanced on their heads to irrigate the onion plots.

Today some villages boast special wells dug at the center of the village garden (bottom right) and reserved for irrigation.

Dressed in their finest garb, young people attend the annual buro *festival—when the Dogon celebrate community ties and the beginning of the rainy season. Money tucked into the woman's headdress shows her family that she is being supported well by her new husband. Old ties still bind, though some 35 percent of the Dogon are now Muslim and worship in mosques like that in Kani Kombolé (below).*

(Continued from page 119) fathers hanged themselves, shamed by their inability to feed their families. Living at the margins is nothing new here. Early in this century, it is said, Dogon threw children off cliffs rather than watch them starve. Perhaps the Tellem, and the Toloy before them, met that awful fate as well.

ON MY LAST AFTERNOON in Dogon country I hiked alone from our camp at Banani up to a plateau where I could see the whole sweep of the escarpment. The cliffs curved away in the low sunlight. Then my eye caught a group of old Tellem granaries, huddled together under a wall. I hiked over to investigate, and 40 feet up the cliff, behind the granaries, I found a small passageway where part of a cave had been bricked up to form a chamber.

I stepped through and waited for my eyes to adjust to the darkness. Twin benches of stone flanked the room, and on each bench lay 30 or 40 corpses, each wrapped in a dusty winding sheet. The indigo-dyed cloth matched the Tellem patterns I had seen. The tomb was in perfect order, undisturbed. I was wild with excitement and a growing agitation. It was getting late and I had to go.

Back in the sunlight I saw a Dogon man, shouldering an ax, sauntering down the valley path just below. He stopped and hacked at a tree. In the windless air, I heard him muttering to himself.

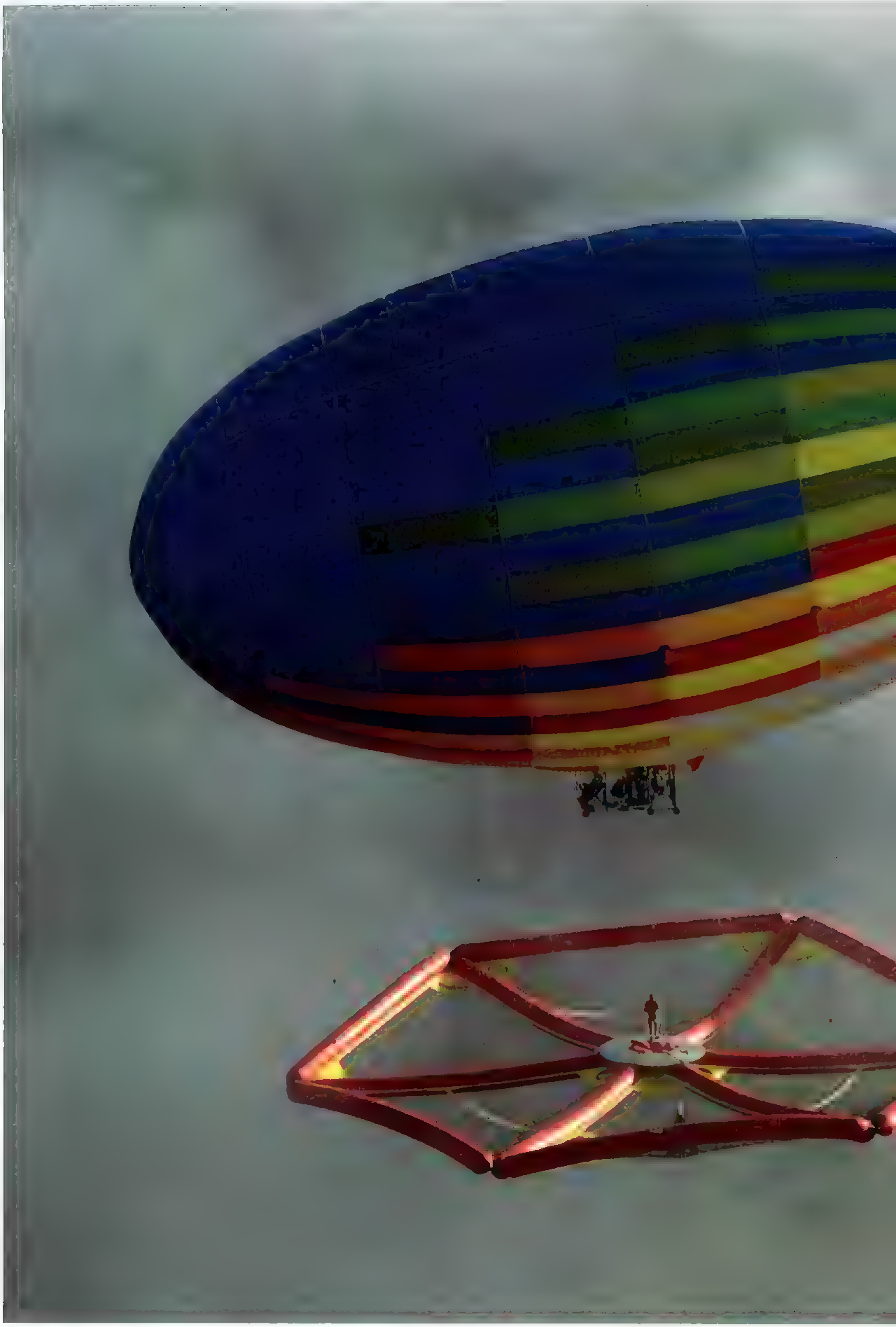
Worried that night would overtake me, I tried to sneak away, scuttling along the wall in a walking crouch, until I rounded a corner and came upon a chilling sight: Almost within reach, on the ledge between the axman and me, lay a stack of 30 wooden funeral stretchers and a cache of blue pots—the accoutrements of Dogon burial. The tomb I had entered was Tellem, but it adjoined a Dogon mausoleum. I had done the unforgivable, blundering alone, without permission, upon a Dogon tomb.

In the valley below, the axman was still at work. I held my breath and silently begged him to quit. He didn't. He worked, rested, worked some more, and stopped again to chat with a friend on his way home from the fields, their voices rising and falling in the dwindling light. It was late when the axman finally left, and I had to rush back to camp, stumbling in the dusk among the boulders. I felt a vast relief and, in that very moment, a flood of shame as well. I could argue that my trespass had been an honest mistake, but I had profaned the peace of the Dogon ancestors, a deep offense against people I had come to like and respect.

When Oumar learned about my misadventure the next day, he seemed unperturbed.

"If the man with the ax had caught you there," he said with the faintest of smiles, "he would have hacked you to bits."

I knew. The Dogon had a right to keep the secret of their graves. It was for them to decide which of the caves should remain unexplored. □



A Raft Atop the Rain Forest

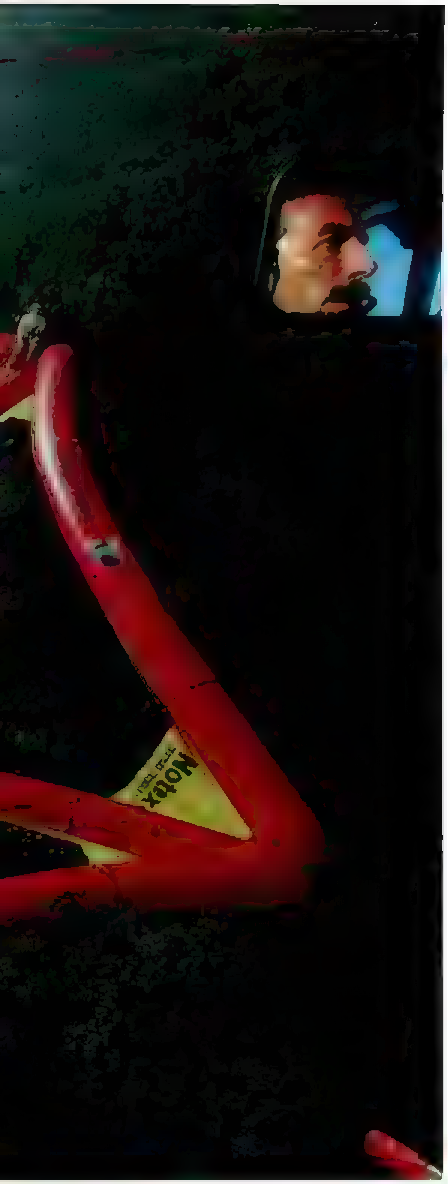
Scientists gain unprecedented access to a tropical forest canopy with an inflatable raft borne by a hot-air dirigible. Architect Gilles Ebersolt rides the hub of his creation to a study site in French Guiana.

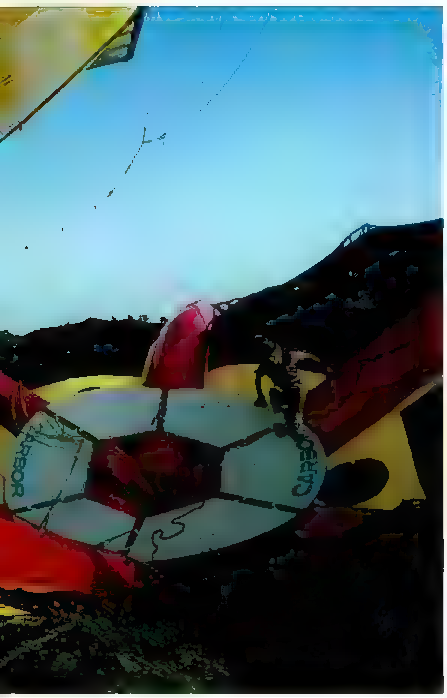
By FRANCIS HALLÉ

Photographs by RAPHAEL GAILLARDE
GAMMA-LIAISON

A TREE HOUSE for research has long been a dream of mine—a dream that reached its culmination in 1989 when I perched atop the rain forest in a raft about the size of a baseball diamond. Formed of inflated rubber pontoons connected by synthetic-fiber netting, the workspace covered more than 600 square meters (6,460 square feet). I was joined by 49 other scientists from eight countries, who rotated using the raft at five sites.

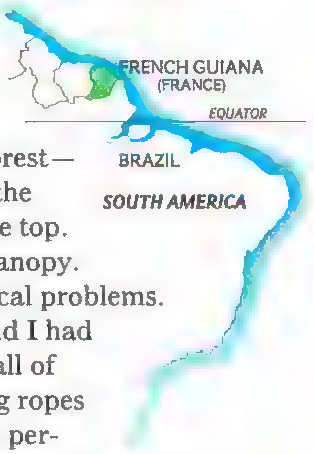
As the dirigible arrives to relocate the raft (right), Ebersolt prepares to attach ropes. When, in a rare mishap, the raft slipped after being released too soon with a heavy load, the airship returned to move it for repairs (above). Shown in the rearview mirror, Dany Cleyet-Marrel pilots the dirigible he helped design, as a dangling TV cameraman films the operation.





WORKING AND SLEEPING aboard a raft where the treetops interlock reminded me of sailing. When the wind came up, the raft undulated on the ocean of green that is the tropical rain forest canopy. With my eyes closed I could imagine myself at sea, except for the sounds: monkeys, insects, birds, frogs, their separate voices becoming a single chorus.

True to its name, the rain forest is wet. Our study area received about four meters (155 inches) of rain during the year of our visit. The transpiration of water vapor was so intense that at night it seemed to rain *up*. By morning everything was soaked.



By day, seen from a bird's-eye view, the canopy is the true face of the forest—bright and abounding with life. Most of the forest's biological diversity is found at the top. Yet relatively little is known about this canopy.

Much of our ignorance is due to logistical problems. In trying to solve them, my colleagues and I had used a number of approaches but found all of them wanting. Relying solely on climbing ropes is uncomfortable and dangerous. Towers permit some proximity, but to only a few trees in a vertical column. Elevated walkways don't always touch the canopy, and they restrict the area of study.

Our solution was to build a raft light enough to settle safely on the treetops for prolonged access and employ a dirigible to move it about.

The part of the French Guiana rain forest where we deployed the raft is uninhabited by humans. Elsewhere in South America and on other continents, the tropical forests are disappearing at an alarming rate, as vast swaths are harvested by loggers and burned to clear land for agriculture. If the destruction isn't stopped, the virgin forests could be gone in 25 years. The resulting environmental damage would be incalculable, and mankind would lose an irreplaceable resource: the gene pool inherent in tropical plants.

A researcher seeking to develop a disease-resistant banana, for example, would have no place to search for hardy, wild plants of the same family to cross with commercially grown varieties. Pineapples, coffee, cacao, oranges, avocados, cassava—all warm-climate plants—could be improved by properly using the genetic resources of the tropical forest.

But to me, all this is secondary to the fundamental reason for saving the rain forest: It was here before man arrived. We have no right to destroy it.

FRANCIS HALLÉ, a professor of tropical botany at the University of Montpellier, France, has studied rain forests in 20 countries. Free-lance photographer RAPHAEL GAILLARDE lives in Paris. This is his first NATIONAL GEOGRAPHIC article.

MUSCLE AND NERVE are the tickets to the top for Brazilian forester Beatriz Armendariz Pereira (left), who cataloged the dimensions of trees. A harness and sliding hand clamps aid ascent to one of the raft's "manholes." The trip can take newcomers half an hour, with practice less than 15 minutes.

We often made the climb in the evening and slept in the raft (facing page) to get a jump on the next day's work. Graduate student Olivier Pascal, at upper right, and my chief assistant, Patrick Blanc, with the French National Center for Scientific Research, nestle in for the night.

During our studies Blanc found empty spaces between the tops of several trees. This little-understood phenomenon, known as "crown shyness," apparently occurs only between trees of the same species.

On the forest floor, illustrator Jean-Louis Tripp (above, at left) and Isabelle Valade, scientific secretary for the mission, gingerly examine a wasp nest.

In the raft Tony Irvine (left), a specialist in pollination ecology, wears jeweler's glasses as he examines flowers for comparison with those in the rain forests of his native Australia.

A VIVID BOUQUET sprouts from a member of the pineapple family held by botanist Guy Joulin. He is secured by a safety line, equipment that I insist everyone use. The plant, a bromeliad called *Aechmea mertinsii*, is an epiphyte, which uses its roots only for holding on to a tree. Nutrition is obtained from bits of dead vegetation washed from higher branches and from the feces

of tadpoles and mosquito larvae that live in water caught by the plant's leaves.

Pierre Grard of the French tropical research center CIRAD holds a laptop computer with a program he developed for identifying plant families by the characteristics called out by his colleagues. A hunting horn was sounded to signal the raft's location and to announce the arrival and departure of the dirigible.

PURPLE BLOSSOMS yield a wealth of tiny creatures for Eric Nancé, an arachnid specialist we nicknamed Spiderman. To gather specimens, he strikes branches with a stick, catching the debris with a device called a Japanese umbrella.

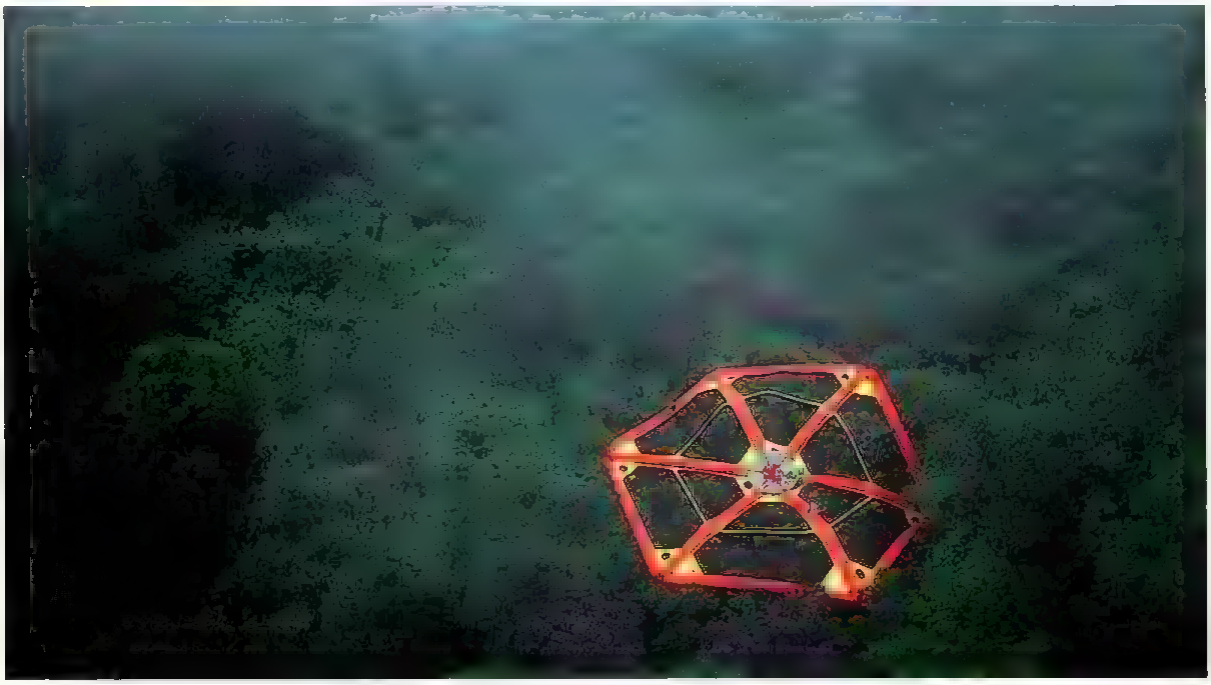
Nancé and his colleagues collected 300 specimens, mainly jumping spiders and crab spiders, including some previously thought to be ground dwellers. Some spiders resembled ants, apparently a way to fool such predators as birds, which generally avoid eating ants because of their bad taste.

The streets of Paris were an ocean away, but the raft helped keep the city in mind. We called the hub of the hexagon Place de l'Étoile, site of the Arc de Triomphe. Each of the six ribs was named for one of the avenues, such as Foch and Champs-Élysées, that meet at the Arc. The outer pontoons were printed with the names of roadways that encircle the city, and the manholes were named after subway stations.

Far from mere sentimentality, these designations gave us several reference points that aided the flow of supplies and personnel between the ground and the raft.

Clutching a sheaf of cuttings after a morning swaying with the raft, Roland Keller gets his land legs back. One of my graduate students in botany, Keller is developing ways to identify woody plants without having to study their fruits and flowers. This helps botanists recognize plants that are too young to flower or those that flower only sporadically, as well as plants that have been cut by natives for medicinal use.

Keller's equipment includes a water jug, kept close at hand to combat dehydration. Filtered river water provided a plentiful supply. Our meals were catered by a firm serving a construction crew that was building a hydroelectric dam nearby. Team members relaxed with group singing and rounds of Ping-Pong played on a table whose net was a strip of 70-mm film donated by a Japanese film crew.



A MORNING'S WORK ends as I prepare to send down bags filled with plant cuttings (right). We found that some canopy trees occasionally shut down food production. The rain forest is notorious for humidity ranging from 95 percent to complete saturation. But at noon on sunny days, humidity can drop to a low 40 percent, so much drier that certain trees stop photosynthesizing.

Our analysis of specimens will continue for months. Although

no new plants have been found, entomologists are certain to report many new insect species.

So far, scientists have identified only about one million insect species in all nature. Estimates of the total on earth range from two million to 30 million or more, the vast majority of them indigenous to tropical forests. Henri-Pierre Aberlenc, an entomologist with CIRAD, calculates that his team collected some 7,000 specimens in the canopy and on the ground below. In a field laboratory (middle) he filters ground-dwelling species into bottles for sorting.

Aberlenc peers at one of his larger finds, a beetle *(Megasoma actaeon)* whose rhinoceros-like horn marks it as a male. About the size of a child's fist, the winged creature can be found in the canopy but usually lives on the forest floor.

Our biggest concern during the project was flies and the diseases they carry. On a previous South American visit, I was bitten on the forehead by a *Phlebotomus* fly, which carries a dangerous parasite. I contracted leishmaniasis, a disease that can disfigure or even kill, but with prompt treatment I was cured.

On his right forearm, Aberlenc carries a scar where fly larvae were removed. He prides himself on having identified them as botfly larvae even before their removal.

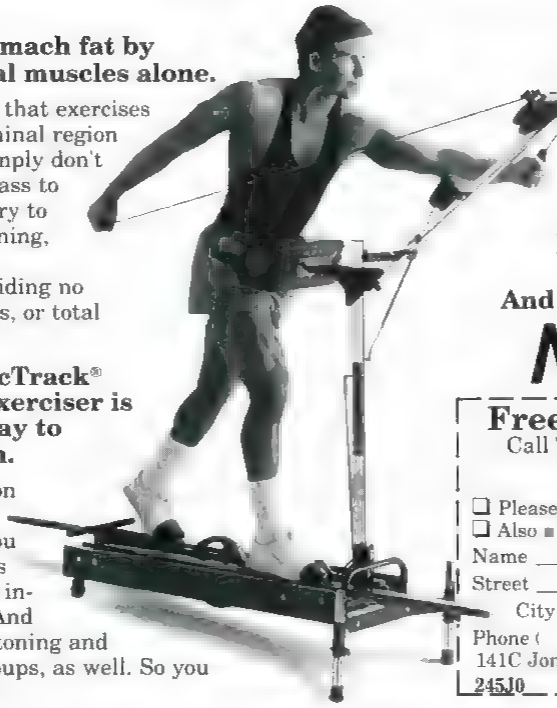
Aberlenc specializes in taxonomy, the classification of living things. "Other fields of science get more publicity and more funding," says Aberlenc. "But taxonomy is vital to the study of the rain forest. You can't know the animal kingdom if you don't know the names." □

An EXPLORER cable TV segment will feature the treetop raft on Sunday, October 7, at 9 p.m. eastern time on TBS SuperStation.

Why it takes legwork to flatten your stomach

You can't reduce stomach fat by exercising abdominal muscles alone.

Research has shown that exercises that work only the abdominal region are not effective. They simply don't involve enough muscle mass to burn the calories necessary to trim fat. Instead of flattening, they merely strengthen underlying muscles, providing no reduction in girth, fatfolds, or total body fat percentage.



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NATIONAL GEOGRAPHIC MAGAZINE OCTOBER 1990

Andean Birds Test Skies for California Condor

The test release of Andean condors in California may pave the way for the reintroduction of the state's native condors, now living only in captivity and totaling 40 birds. The success of the program proved that zoo-raised condors can survive in the wild.

Between 1988 and 1990, 13 South American fledglings, raised in captivity in the U. S., were released by the U. S. Fish and Wildlife Service and the Los Angeles Zoo in the 1.75-million-acre Los Padres National Forest, near Santa Barbara. The vultures quickly learned to soar (right); at maturity their wingspan will reach ten feet, slightly wider than the California condor's. The young birds found the food set out to aid their survival, and ten of them adjusted successfully. They will eventually be recaptured to augment populations in South America and to prevent crossbreeding after the California condors are released.

The hatching this year of eight California condors has made biologists optimistic that these giants may return to the California skies by 1992.

MICHAEL WALLACE, LOS ANGELES ZOO

Harnessing Greenhouses to Purify Sewage

While not yet ballyhooed as a tourist attraction, a waste-treatment plant on Cape Cod is drawing city officials from around the world to see a sunlit army of organisms turn waste into clean water.

DANN BLACKWOOD

"Many of the chemicals used in conventional waste treatment actually add to the pollution of the water supply," says John Todd (below left), an environmental inventor. "My system moves sewage by gravity through a series of tanks in a greenhouse, where hundreds of species of plants and animals break it down naturally."

In April the town of Harwich, Massachusetts, population 9,000, began using Dr. Todd's system to handle a third of its septage—the highly concentrated waste collected from septic tanks. The facility takes as much room as a conventional treatment plant but should operate at lower cost.

In a step-by-step process, bacteria digest the organic matter and convert ammonia into nitrates on which algae and duckweed thrive. Zooplankton and snails feed on the algae, fish eat the zooplankton, and floating plants soak up the leftovers. Bulrushes, cattails, and water hyacinths render toxins harmless by breaking them down into constituent parts. Heavy metals, such as copper and lead, are absorbed into the tissues of trees to be transplanted outside.

By-products of the cleanup system can be sold, he says, including decorative plants and minnows for bait. In Louisiana, Mississippi, Florida, and California, natural systems using aquatic plants now process sewage in man-made, open-air lagoons. Dr. Todd's greenhouse concept makes this kind of natural sewage treatment possible in the North as well.

Glasnost Produces a Death Ray for Locusts

A Soviet scientist and a U. S. scientist, friends for 15 years, are teaming up with laser weaponry to fight an old enemy of humankind, locusts. In swarms half a mile thick, the insects quickly defoliate hundreds of square miles. Crop damage in Africa and the Middle East can reach 200 million dollars a year.

Peter A. Franken of the University of Arizona was hosting Vladilen S. Letokhov from the Institute of Spectroscopy in Moscow when they came up with a plan. "Remote sensing from high-flying U-2 aircraft can locate the locusts by their trail of defoliation," says Dr. Franken.

STEVE McCURRY, MAGNUM

"Far from any human settlements, we'll aim a ten-foot-wide laser beam from an airplane or helicopter, roasting the swarm. This would be less harmful to the environment than using poisonous chemical controls."

Soviet and U. S. officials have expressed enthusiasm for the plan.

The numbers outside.

BOB MARTIN, LIGHTHAWK

Pilots Help Preserve Belize Wilderness

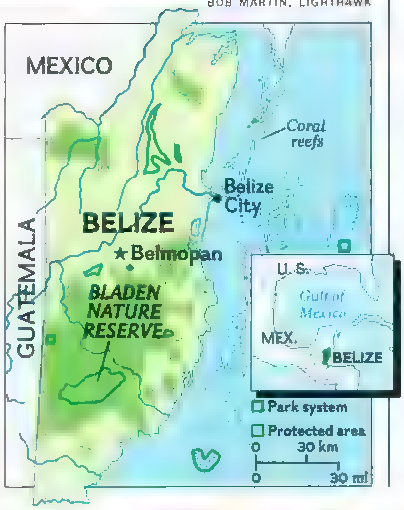
An unofficial environmental air force made up of a group of U. S. pilots has helped Belize set aside its largest protected area—the 152-square-mile Bladen Nature Reserve. The organization, called Lighthawk, provided a low-flying single-engine plane to give "a bird's-eye view to officials, many of whom had never seen the area," said Victor Gonzalez, head of the Belize Department of the Environment. "The flights were instrumental in convincing officials that the area should be saved."

The 11-year-old nonprofit group, based in Santa Fe, New Mexico, owns three airplanes and calls on nearly 60 volunteer pilots with their own planes for environmental missions.

Only scientific research and educational activities may take place in Belize's new reserve, once targeted for logging. The upland watershed is the site of Maya ruins and home to several endangered species. Mountain lions, Baird's tapirs, white-lipped peccaries, and at least 190 species of birds also inhabit the reserve's lush rain forests, clear rivers, and rocky outcrops.

Lighthawk also sponsored an earlier ground expedition into the area and helped prepare a report calling for its protection.

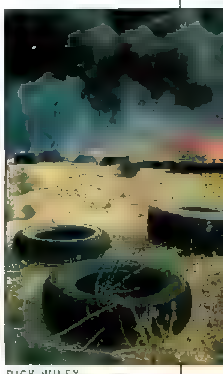
"We hope this farsighted action by the Belize government will rub off on the U. S. Congress and encourage members to stop the destruction of America's temperate rain forests," says founder Michael Stewartt. Lighthawk flights over Washington State have already helped challenge the high estimates by the U. S. Forest Service of remaining old-growth forests in the Pacific Northwest (NATIONAL GEOGRAPHIC, September 1990).



New Journeys for Old Tires

Finding new uses for the 275 million tires discarded annually in the U. S. and Canada could help reduce pollution and the visual blemish on North American landscapes. Tire dumps often catch fire or are mischievously set ablaze, as here in Tucson, Arizona. The flames release black particles, carbon dioxide, and sulfur dioxide—a compound contributing to acid rain.

Efforts to recycle tires include freezing and shattering them into crumbled rubber, which can be used in asphalt paving for roads and runways. Tires are also cut up for doormats or shredded for floor coverings. Left whole, they can serve as breakwaters or artificial reefs.

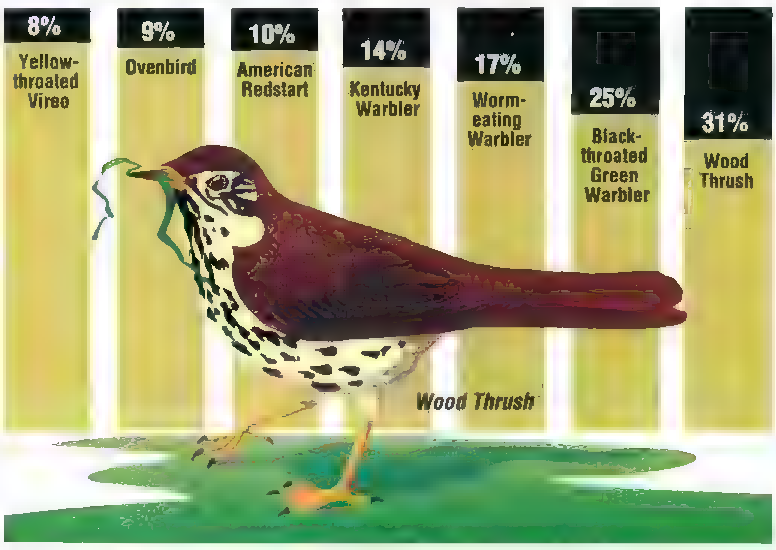


RICK WILEY

A power plant in Westley, California, burns as many as 800 tires an hour, converting them to energy. The tires are burned at extremely high temperatures for total combustion. This process virtually eliminates particle emissions and reduces sulfur dioxide, which is further neutralized by limestone scrubbers.

A residential project at Taos, New Mexico, piled dirt-filled tires and covered them with adobe to form walls in 70 homes.

Migratory songbird decline 1978-1987



ART BY MARK HOLMES, NGS. SOURCE: U. S. FISH AND WILDLIFE SERVICE

Songbirds that winter in Central and South America have declined in the eastern U. S. and Canada. Among possible reasons: rain forest destruction in the wintering grounds and increased predation in the north by raccoons and other animals that have adapted to human development.

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"IT WAS A REAL BLESSING," Frances Vaughn said after volunteers from the Christmas in April program gave her house a face lift.

"A whole slew of people gave up their weekend to help me. They fixed my back porch. Painted every room. Gave me a stove. They even put a brand-new roof on. I could've kissed every one of them."

This neighborly love is being rekindled all over America, thanks to Christmas in April.

Thousands of people from all walks of life are banding together to help the poor, the elderly, the handicapped.

By repairing homes, these caring volunteers are doing more than painting and hammering.

They're restoring dignity, hope and pride.

"TODAY I fell in LOVE with TWENTY perfect STRANGERS."

FRANCES VAUGHN

Washington, D.C.

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The launch of Christmas in April☆USA was made possible through the commitment of many people and corporations, including a grant from the Toyota USA Foundation. We're proud to say we've been a supporter from the very start.

As a result, the national body has been able to help more communities start local programs. (The number has grown from 13 to 43 in just two years.)

Frances Vaughn is certainly thrilled the folks around Washington rallied behind Christmas in April.

In fact, she would have jumped through the roof with joy if it hadn't just been repaired.

TOYOTA

INVESTING IN THE INDIVIDUAL

On Assignment

"DANGLING hundreds of feet off the ground in 130-degree temperatures, he remained completely focused and fearless," a longtime climbing partner said of free-lance photographer JOSÉ AZEL, who rappelled down a 500-foot cliff (right) and edged through tight crevices of Mali's Bandiagara escarpment (lower) to photograph the Dogon caves featured in this issue.

"Climbing does not have to be dangerous," José said. "You have to set limits and not allow the excitement of the moment to push you beyond those limits. Then the risks are rather low."

José's love of climbing is second only to his love of photography, which he took up as a hobby while he was an English major at Cornell University. He later combined his writing with photography in a master's program in photojournalism at the University of Missouri.

Now based in Maine, José has covered U. S. politics for *Time* magazine, captured world record-holders at the Olympic Games, and trekked across Alaska. For the January 1989 GEOGRAPHIC he documented Colombia's cocaine production, emerging unscathed.

Photographing illicit dealings was not the only danger on that assignment. "We were faced with riding mules down steep trails in the Sierra Nevada de Santa Marta," says Peter White, author of the story. "I'm not experienced with mules, but José reassured me and showed me when to lean forward and when to lean backward. I was very glad he was there."

José's natural curiosity helped him establish a rapport with the Dogon. He went straight to the task of communicating with the people—sometimes through as many as three interpreters—as soon as he entered a village. He took time from his schedule to teach English to inquisitive children and show them how to climb, and he spent many nights huddled by a fire with a village schoolteacher who craved news of the outside world.

BOTH BY JOSEPH LENTINI

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PRECIOUS METAL

The "tin" can may just be the world's perfect container. It's made of durable, high-grade steel that is completely recyclable.* It saves energy because it requires no refrigeration. And the can is made, shipped and stored more economically than other packages. So the dollars you spend go more to the food you eat than the package that contains it. The steel can. Precious little could be done to improve it.

FOOD FOR THOUGHT

Del Monte Quality

*Del Monte supports steel can recycling. For information about recycling in your area, please contact the Steel Can Recycling Institute, 680 Anderson Drive, Pittsburgh, PA 15220.

(Low light captured on Normal* film.)

(Low light captured on Fujicolor Super HG400.)

THE ONLY

The chair gently rocks and your child's eyes flutter closed, thumb slowly drifting toward its destination. This very special moment could be ruined in a flash. But how else, in this limited light, can it be captured?

DIFFERENCE

And will your everyday film rise to the challenge? May we suggest Fujicolor Super HG400. With Super HG400 the moment and the action are frozen in time, with a vibrancy, clarity and fineness

IS THE

of grain that, even in low light, you hadn't thought possible. You might want to keep some close at hand. After all, perfect moments don't always happen in perfect light. FUJI. A new way of seeing things.

FILM.

FUJICOLOR SUPER HG 400.

*100 ISO Print Film.

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